Weeds

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Weeds

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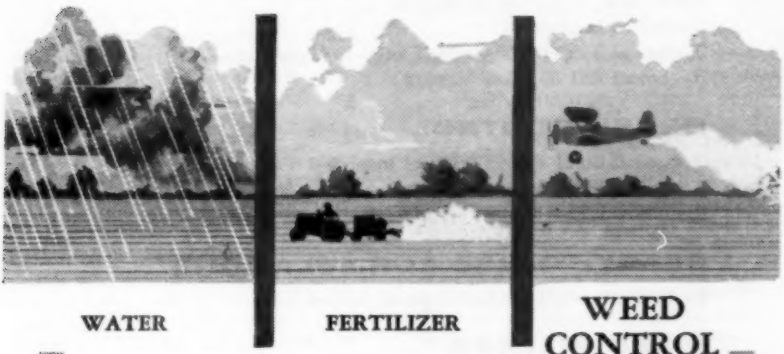

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Publication Policies for WEEDS[1]

K. P. Buchholtz[2]

WEEDS was established in 1951 to meet the need for a publication that reached workers in all fields of weed control throughout the United States. It was also believed that a journal devoted exclusively to weed control would serve to promote interest and facilitate progress in this new and rapidly expanding field. In January 1956 WEEDS was designated as the official publication of the newly organized Weed Society of America. As such, it represents and contacts the largest organized group of weed workers in the world.

Since it was established in 1951 the Editors and Editorial Committees of WEEDS have endeavored to prepare a journal consisting of reliable, factual and pertinent papers on all phases of weed control. Attempts have been made to publish manuscripts on regulatory, extension, educational and research activities. It is evident that WEEDS has had modest success. Over 1000 copies of each issue of Volume IV were distributed and the subscription list continues to grow. WEEDS is widely distributed among weed workers across the United States and Canada and to a limited extent in foreign countries. This journal is distributed to 112 libraries in the United States and to 64 in foreign countries. As a result WEEDS is placed on permanent file in many more libraries than any other weed publication.

A review of the advantages of subscribing to, and contributing to, WEEDS may be of value. WEEDS is a bonafide publication and regularly supplies reprints of the manuscripts it prints. Such reprints and other evidences of progress are considered favorably by administrators when the records of weed workers are evaluated. The extensive subscription list and the wide distribution to libraries allows a large number of your co-workers to review and benefit from your studies when they are published in this journal. WEEDS provides an outlet for comprehensive, detailed papers that are difficult to publish in other periodicals. Figures and photographs can be included in the manuscript as desired. The paper and binding of WEEDS are such that this publication will remain in good condition for many years in private and public libraries. In summary WEEDS provides a means of publishing scholarly papers in the field of weed control, ensures their wide distribution to workers primarily interested in this field and allows permanent filing in numerous libraries throughout the world. No other publication can provide these facilities as well as can WEEDS.

It is our conviction that the WEEDS journal can be improved substantially. This improvement can come about only with your cooperation and the cooperation of the other members of the Weed Society of America. The most serious problem results from the small

[1]Presented at the North Central Weed Control Conference, Dec. 10, 1956.
[2]Dept. Agronomy, Univ. of Wisconsin, Madison.

supply of manuscripts submitted for publication. Our budget allows us to print 128 pages per issue. About 28 pages are required for the Bibliography of Weed Investigations and miscellaneous items. This leaves 100 pages for papers in each issue. During the first three volumes of WEEDS papers totaled about 58 pages per issue. During Volume IV about 65 pages of manuscripts were printed in each issue. The prospects for Volume V are no better. It is obvious that we are not fully utilizing our opportunities for publication in WEEDS. It appears that we all value the material published but few make the effort to, or secure the benefits from, publishing in this journal.

It may be helpful to review the procedure followed when a paper is submitted for publication. All manuscripts received are reviewed by two workers familiar with the field of activity covered by the paper. The reviewers are instructed to make comments and to criticize the paper for it is our firm belief that comments are most valuable when made prior to printing. The author is given the opportunity to make such revisions as he believes justified. The revised paper is then in order for publication. Review and revision usually require about 2 or 3 months. Publication after a paper is submitted is relatively rapid but since the journal is a quarterly, publication may not occur for as long as six months after it is submitted.

Not all manuscripts submitted are finally printed. Some have been printed in substantially the same form elsewhere before being submitted to WEEDS. We do not believe that re-publication can be justified for our costs average $12.00 per page. We believe that the proceeds from your subscriptions should be used to encourage the publication of new, original, previously unreported material. Consequently manuscripts are returned to the authors when they are known to have been published in a proceedings of one of the weed conferences or in any other journal. Material that has appeared only in abstract form in the Research Report of the NCWCC or in conference proceedings is accepted for publication.

Occasionally a manuscript may receive so many comments that the author becomes discouraged and does not re-submit the manuscript. Revisions in content or interpretation are made by the choice of the author. He may accept the suggestions and make revisions or if he chooses he may re-submit the paper as originally prepared. Controversial points will of course reflect on the ability of the author.

At times manuscripts are not acceptable due to the form used in their preparation. It is the responsibility of the editor to secure a uniformity of style and arrangement. Printing requirements impose certain standards that must be maintained. Uniformity of style makes the journal easier to read and contributes to its general appearance.

The problem of manuscript shortage can only be solved by individual choice. There is ample material available each year to fill WEEDS several times over. During each of the past several years the material published by the NCWCC alone would more than fill 400 pages of WEEDS. The other weed conferences publish somewhat less material but there is no doubt that in the aggregate a substantial amount of material is released in the field of weed control each year.

It is probable that a considerable number of the more detailed, comprehensive studies could more profitably be published in WEEDS than in conference publications. If desired, abstracts of the material might be submitted for regional distribution.

It is my hope that in the future you will consider WEEDS seriously as an outlet for the significant papers on weed control that you prepare. Publication will be somewhat more involved than with regional publications but not seriously so. Benefits derived from publication in WEEDS will be substantially greater. When this practice becomes widespread WEEDS will become an even more informative and useful journal than it is today.

Weeds

JOURNAL OF THE WEED SOCIETY OF AMERICA

VOLUME V APRIL 1957 NUMBER 2

The Selective Herbicidal Properties of Several Variously Substituted Phenoxyalkylcarboxylic Acids

W. C. SHAW and W. A. GENTNER[1]

THE discovery of the herbicidal properties of the phenoxyalkylcarboxylic acids created an impetus in research on the development of new herbicides. A number of these compounds are now being used commercially as pre-planting, pre-emergence, and post-emergence treatments for the control of dicotyledonous and monocotyledonous, annual and perennial weeds in a variety of weed-crop situations.

Several of these compounds, including 2,4-dichlorophenoxyacetic acid (2,4–D), 2–methyl–4–chlorophenoxyacetic acid (MCPA), 2,4,5–trichlorophenoxyacetic acid (2,4,5–T), and 2–(2,4,5–trichlorophenoxy)propionic acid [2–(2,4,5–TP)], are estimated to have a combined annual weed control usage on more than 30 million acres of cultivated land in the United States. Nevertheless, there are many weed-crop situations in which the selectivity and specificity of the substituted chlorophenoxyacetic and alpha-chlorophenoxypropionic acids are not adequate to control the weeds without causing serious injury to the associated crops.

Weeds are serious competitors in forage crops, especially in the seedling and establishment phases of growth. The herbicides 2,4–D, 2,4,5–T, and MCPA are used for the control of weeds and woody plants on rangelands, native grasslands, and to a less extent on established grass-legume pastures. However, there are few, if any, herbicides that may be used efficiently to control annual and perennial dicotyledonous weeds in pure stands of forage legume seedlings or in seedling stands of mixtures of forage legumes and grasses.

It is estimated that more than 36 million acres of small grains [wheat *(Triticum aestivum)*, oats *(Avena sativa)*, barley *(Hordeum vulgare)*, and rye *(Secale cereale)*] are underseeded with one or more of the following legumes: alfalfa *(Medicago sativa)*, red clover *(Trifolium pratense)*, Ladino clover *(Trifolium repens)*, alsike clover

[1]Plant Physiologists, Field Crops Research Branch, Agricultural Research Service, United States Department of Agriculture, Beltsville, Md. The authors wish to acknowledge the cooperation of personnel of the Research Divisions of the American Chemical Paint Company, Ambler, Penn.; May and Baker Ltd., Daggenham, England; and the Dow Chemical Company, Midland, Mich. in synthesizing and supplying the experimental compounds included in these studies.

(Trifolium hybridum), sweetclover *(Melilotus* spp.), the annual lespedezas *(Lespedeza* spp.) and others or various mixtures of these. The underseeded small grains are usually infested with one or more of the following weeds: wild mustard *(Brassica kaber)*, yellow rocket *(Barbarea vulgaris)*, wild onion *(Allium canadense)*, wild garlic *(Allium vineale)*, wild radish *(Raphanus raphanistrum)*, Canada thistle *(Cirsium arvense)*, field bind-weed *(Convolvulus arvensis)*, lambsquarter *(Chenopodium album)*, ragweed *(Ambrosia artemisiifolia)*, and others. There is also an important need for improved selective herbicides that may be used to control weeds in canning peas, flax, forage legume seed-production fields, and in tolerant crops such as corn and rice when they are grown in the vicinity of cotton, grapes, and other crops which are highly susceptible to injury from drift of the phenoxyacetic and alpha-phenoxypropionic acids.

An early study revealed some of the limitations inherent in using 2,4–D for the control of weeds in small grains underseeded with forage legumes (12). More recent investigations, conducted by numerous workers, have also revealed some of the limitations involved in the use of MCPA, 3,4–dichlorophenoxyacetic acid (3,4–DA), and 4–chlorophenoxyacetic acid (4–CPA) for the control of weeds in small grains underseeded with legumes.

The study reported herein was an attempt to expand our knowledge of the selective herbicidal properties of the phenoxyalkylcarboxylic acids by investigating the relationships among structural configuration, specificity, mode of action, and the herbicidal effectiveness of these compounds for the control of weeds in a number of important weed-crop situations.

REVIEW OF LITERATURE

The synthesis of 2,4–D and other chlorophenoxyacetic acids (10) stimulated research on structural configuration in relation to mode of action, growth-modifying activity, and the selective herbicidal properties of this important group of compounds and related chemicals. The literature on these and related investigations is too voluminous to review in this paper. However, some of the literature that has a direct bearing on these investigations will be cited.

Studies have been in progress almost continuously on the relationship between structural configuration and the growth-modifying activity of chemicals since the discovery of the heteroauxin (7). These studies collectively have established that for physiological activity in the aryloxyalkylcarboxylic acids some of the minimum structural requirements include: (a) a six-membered unsaturated ring with a side chain which contains an alpha-hydrogen, (b) a critical electron density at the two ortho positions, and (c) two unsubstituted positions para to each other (2, 4, 6, 7, 8, 9, 16, 21). Inconsistencies with respect to physiological activity based on these structural requirements have been reported (17). It would appear that the present theories on structure in relation to activity are not completely satisfactory in explaining the growth-modifying activities of the phenoxyalkylcarboxylic acids.

The mode of action and metabolism of the aryl- and aryloxyalkylcarboxylic acids in plants have been studied in numerous investigations. However, early studies on the metabolism of chemicals in animals revealed that certain chemicals underwent significant changes. Knoop (5) showed that beta-phenylpropionic acid and delta-phenylvaleric acid, when fed to dogs, were beta-oxidized to benzoic acid which was eliminated in the urine in the form of hippuric acid (benzoyl glycine). This finding served to stimulate investigations on the possibilities that the molecules of growth-modifying chemicals might be degraded by similar mechanisms in plants.

Thompson et al. (15) using three different plant bio-assay techniques showed that 4–(2,4–dichlorophenoxy)butyric acid [4–(2,4–DB)] and 4–(4–chlorophenoxy)butyric acid [4–(4–CPB)] and a large number of related and unrelated compounds were highly active growth-modifying chemicals.

Synerholm and Zimmerman (14) synthesized and studied the physiological activity of a series of omega–(2,4–dichlorophenoxy) carboxylic acids and related compounds in relation to their biochemical role as plant growth modifiers. In this series of compounds the length of the carboxylic acid side chain varied progressively from 2 carbon atoms in the simplest member, 2,4–dichlorophenoxyacetic acid, to 8 carbons in eta–(2,4–dichlorophenoxy)caprylic acid. Using a tomato leaf epinasty test as a bio-assay evaluation technique, Synerholm and Zimmerman observed that the homologues with an even number of carbon atoms in the side chain were active and that those with an odd number of carbon atoms were inactive except for non-systemic activity at the point of application. This periodicity in activity led these workers to suggest that the members of the series higher than 2,4–dichlorophenoxyacetic acid were inactive *per se*, but were converted by the plant either to the active acetic acid homologue or, in other cases, to an inactive metabolic product. They also assumed that these acids were beta-oxidized by enzymes in the plants and pointed out that if the oxidation resulted in the removal of two carbons in each step, only those members possessing even-numbered carbon chain acids could give rise to the active acetic member of the series. They cited Knoop's work on animal metabolism of fatty acids (5) to support their data and assumptions.

In a series of investigations, Wain and his colleagues (2, 3, 18, 19, 20) studied the growth-regulating activities of a series of omega-substituted alkylcarboxylic acids. These investigators using bio-assay, chromatographic, and chemical techniques confirmed the previous work, assumptions, and suggestions by Synerholm and Zimmerman that omega-substituted phenoxyalkylcarboxylic acids containing an even number of carbon atoms in the side chain could be degraded in plants to the highly active acetic acid derivatives. These considerations led Wain (19, 20) to postulate the possibility of using certain of the butyric, caproic, and octanoic (caprylic) derivatives for the selective control of weeds based on the differences in the enzymatic constitution of plants, and the property of certain enzyme systems to metabolize inactive compounds to herbicidally active derivatives.

MATERIALS AND METHODS

Greenhouse Studies

In the greenhouse studies, randomized split, split-plot experimental designs with four replications were used. The test species were grown separately in one quart capacity styrene containers. A high seeding rate was used, and the plants were thinned to a uniform number per container for each species. The test plants were subirrigated throughout the investigations. The following test species, followed by the number of plants per container, were included in the greenhouse studies: white clover–10 *(Trifolium repens)* var. Pilgrim, red clover–10 *(Trifolium pratense)* var. Kenland, sweetclover–10 *(Melilotus officinalis)* var. Madrid, alfalfa–10 *(Medicago sativa)* var. Atlantic, flax–6 *(Linum usitatissimum)* var. Cascade, buckwheat–4 *(Fagopyrum esculentum)*, soybeans–2 *(Soja max)* var. Hawkeye, rape–4 *(Brassica napus)* var. Dwarf Essex, oats–6 *(Avena sativa)* var. Clinton 59, and corn–2 *(Zea mays)* var. US 13. The chemically pure phenoxyalkylcarboxylic acids listed in Table 1 were formulated using a 1:1 mixture of acetone and water containing one percent by volume (final concentration) of polyoxyethylene sorbitan monolaurate.[2] The acids were applied as foliage sprays with an experimental sprayer (11) operating at 30 psi and delivering 40 gallons of the acetone-water carrier per acre. At the time of treatment, the forage legumes were 2 to 3 inches tall, *Brassica napus* 5 inches tall, and all other species were 6 to 10 inches tall. The formulation-carrier was applied as a control and was found to be non-toxic to the test species.

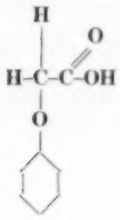
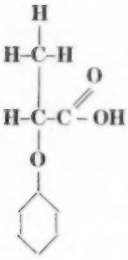
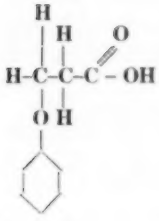
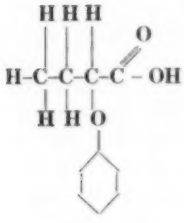
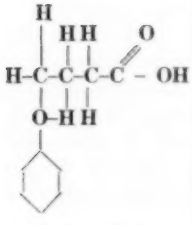
The response data were recorded 30 days after treatment and included the following evaluation criteria: (a) injury score rating of 0 to 10, (b) height in inches, and (c) green weight of the above ground plant parts. The height and weight of the test species were converted to the percentage height reduction and percentage weight reduction respectively as compared to untreated checks.

Experiments with the 25 compounds in Table 1 were repeated four times using rates of ¼, ½, 1, 2, and 4 pounds per acre and essentially the same test species. However, in the interest of brevity, and because the results of the individual experiments were highly reproducible, only the weight reduction data from a single complete series of the compounds at rates of ¼, ½, and 1 pound per acre are presented.

In the first study, rape *(Brassica napus)*, hereafter referred to as "brassica", was used as a test species with the assumption that it was typical of weedy brassicas, and because of the ease with which it grew under greenhouse conditions. However, since mustard *(Brassica kaber)* is a serious weed in grain fields underseeded with legumes, it also seemed desirable to study the response of this species to several of the more promising phenoxyalkylcarboxylic acids. Mustard was grown for these studies using the same methods as described for the other species. The same evaluation criteria were also used. How-

[2]Experimental quantities were supplied as Tween 20 by the Atlas Powder Company, Wilmington, Delaware.

Table 1. Series of phenoxyalkylcarboxylic acids studied in these investigations.

Side Chain Substitutions	Ring Substitutions
	(a) Phenoxyacetic Acids 2,4-dichlorophenoxyacetic acid (2,4-D) 2-methyl-4-chlorophenoxyacetic acid (MCPA) 2,4,5-trichlorophenoxyacetic acid (2,4,5-T) 3,4-dichlorophenoxyacetic acid (3,4-DA) 4-chlorophenoxyacetic acid (4-CPA)
	(b) Alpha-phenoxypropionic Acids 2-(2,4-dichlorophenoxy) propionic acid [2-(2,4-DP)] 2-(2-methyl-4-chlorophenoxy)propionic acid[2-(MPP)] 2-(2,4,5-trichlorophenoxy) propionic acid [2-(2,4,5-TP)] 2-(3,4-dichlorophenoxy)propionic acid [2-(3,4-DP)] 2-(4-chlorophenoxy)propionic acid 2-(4-CPP)
	(c) Beta-phenoxypropionic Acids 3-(2,4-dichlorophenoxy)propionic acid [3-(2,4-DP)] 3-(2-methyl-4-chlorophenoxy)propionic acid [3-(MCPP)] 3-(2,4,5-trichlorophenoxy)propionic acid [3-(2,4,5-TP)] 3-(3,4-dichlorophenoxy)propionic acid [3-(3,4-DP)] 3-(4-chlorophenoxy)propionic acid [3-(4-CPP)]
	(d) Alpha-phenoxybutyric Acids 2-(2,4-dichlorophenoxy)butyric acid [2-(2,4-DB)] 2-(2-methyl-4-chlorophenoxy)butyric acid [2-(MCPB)] 2-(2,4,5-trichlorophenoxy)butyric acid [2-(2,4,5-TB)] 2-(3,4-dichlorophenoxy)butyric acid [2-(3,4-DB)] 2-(4-chlorophenoxy)butyric acid [2-(4-CPB)]
	(e) Gamma-phenoxybutyric Acids 4-(2,4-dichlorophenoxy)butyric acid [4-(2,4-DB)] 4-(2-methyl-4-chlorophenoxy)butyric acid [4-(MCPB)] 4-(2,4,5-trichlorophenoxy)butyric acid [4-(2,4,5-TB)] 4-(3,4-dichlorophenoxy)butyric acid [4-(3,4-DB)] 4-(4-chlorophenoxy)butyric acid [4-(4-CPB)]

ever, in the mustard response studies, randomized split, split-plot experimental designs with five replications were employed.

Field Studies

The phenoxyacetic, alpha-phenoxypropionic and gamma-phenoxybutyric acids in Table 1 were also applied as pre- and post-emergence sprays to 25 test species under field conditions at Beltsville, Maryland. The results of these studies are omitted from this paper, but have been summarized in detail elsewhere (13).

EXPERIMENTAL RESULTS

Greenhouse Studies

The responses of the test species to each of the phenoxyalkylcarboxylic acids applied as foliage sprays are indicated in Tables 2, 3, 4, and 5, and Figures 1, 2a, 2b, 3, and 4.

The data in Table 2 indicate that all the phenoxyacetic acids were active on all species. MCPA was less injurious to red clover, flax, and oats than 2,4–D, but was as active as 2,4–D on white clover, sweetclover, alfalfa, buckwheat, and brassica. The 3,4–DA was less inhibitory to white clover and alfalfa than MCPA or 2,4–D, but was more injurious to flax and less active on brassica than 2,4–D or MCPA. The 2,4,5–T was more active than any of the other derivatives on all species except buckwheat and brassica. The 4–CPA was less injurious to white clover than any of the other derivatives and was also less active on red clover than any other derivative except MCPA.

The herbicidal activity of the alpha-phenoxypropionic acids on

Table 2. The effect of five ring substitutions on the selectivity of several phenoxyacetic acids.

Chemical	Rate lb/A	Percentage reduction in green weight yield									
		W. clover	R. clover	S. clover	Alfalfa	Flax	Buckwheat	Soybeans	Brassica	Oats	Corn
2,4–D	¼	77	90	88	90	47	51	49	92	12	1
	½	91	98	92	94	62	77	54	92	19	0
	1	99	98	97	96	88	97	82	94	6	16
	Av.	89	95	92	93	66	75	62	93	12	6
MCPA	¼	56	38	85	94	32	65	58	79	2	2
	½	90	52	90	92	17	63	76	98	7	17
	1	99	72	98	96	30	94	93	93	2	11
	Av.	82	54	91	94	26	74	76	90	4	10
2,4,5–T	¼	99	95	90	91	88	54	92	77	12	8
	½	99	98	96	96	89	70	95	68	7	15
	1	99	99	94	95	95	82	95	94	18	17
	Av.	99	97	93	94	91	69	94	80	12	13
3,4–DA	¼	38	65	36	18	66	18	54	53	9	20
	½	56	82	43	32	82	51	91	64	8	0
	1	87	95	84	65	92	55	78	92	12	15
	Av.	60	81	54	38	80	35	74	70	10	12
4–CPA	¼	21	42	1	32	38	20	49	68	6	0
	½	26	63	21	55	38	22	70	89	14	17
	1	60	90	77	86	83	26	78	85	14	19
	Av.	36	65	33	58	53	23	69	81	11	12

the test species except for soybeans was very similar to that of the phenoxyacetic acids (Table 3). Soybeans showed considerably more

Table 3. A comparison of the effect of five ring substitutions on the selectivity of several phenoxyacetic and alpha- and beta-phenoxypropionic acids.

Chemicals applied at ½ lb/A	Percentage reduction in green weight yield						
	W. clover	R. clover	Alfalfa	Soybeans	Brassica	Oats	Corn
2,4–D	100	100	100	95	100	3	35
2–(2,4–DP)	99	100	98	43	98	2	47
3–(2,4–DP)	28	19	13	2	12	0	8
MCPA	100	63	100	100	100	10	45
2–(MCPP)	100	81	100	77	96	0	49
3–(MCPP)	0	28	2	0	0	0	26
2,4,5–T	100	100	100	100	100	21	39
2–(2,4,5–TP)	100	100	100	100	100	0	35
3–(2,4,5–TP)	28	17	20	0	10	0	21
3,4–DA	91	93	74	100	98	0	25
2–(3,4–DP)	91	93	88	94	96	0	36
3–(3,4–DP)	15	16	18	0	5	0	17
4–CPA	66	77	18	92	85	3	37
2–(4–CPP)	43	44	48	39	76	4	20
3–(4–CPP)	10	5	19	0	0	0	30

tolerance to 2–(2,4–dichlorophenoxy)propionic acid [2–(2,4–DP)] than to 2,4–D. The beta-phenoxypropionic acids, however, possessed little or no systemic activity, but exhibited a very low order of localized contact phytotoxicity which resulted in some temporary chlorosis.

The activity of the alpha-phenoxybutyric acids is indicated in Table 4. The compounds 2–(2,4–dichlorophenoxy)butyric acid [2–(2,4–DB)], 2–(2–methyl–4–chlorophenoxy)butyric acid [2–(MCPB)], and 2–(2,4,5–trichlorophenoxy)butyric acid [2–(2,4,5–TB)] showed high activity on white clover, red clover, sweetclover and alfalfa, but possessed low activity on oats, corn, and brassica. The much lower activity of 2–(3,4–dichlorophenoxy)butyric acid [2–(3,4–DB)] and 2–(4–chlorophenoxy)butyric acid [2–(4–CPB)] as compared to the higher activity of 2–(2,4–DB), 2–(MCPB) and 2–(2,4,5–TB) on the test species is significant. Although lower general activity was associated with the 3,4–dichloro and 4–chloro derivatives as compared to the 2,4–dichloro, 2–methyl–4–chloro, and 2,4,5–trichloro substitutions among the phenoxyacetic and alpha-phenoxypropionic acids, the magnitude of the differences in activity was not as great as among the same substitutions in the alpha-phenoxybutyric acids (Tables 2, 3, and 4).

A comparison of the response data for the gamma-phenoxybutyric, phenoxyacetic, alpha-phenoxypropionic, and alpha-phenoxybutyric acids indicates that only in the gamma-phenoxybutyric acids was the general level of inhibitory action of the 3,4–dichloro and 4–chloro derivatives greater on the legume species than the 2,4–dichloro, 2–methyl–4–chloro, and 2,4,5–trichloro substitutions. The selective action of the gamma-phenoxybutyric acids among the different species is strikingly evident in Figures 1 and 4 and Table 5.

Table 4. The effect of five ring substitutions on the selectivity of several alpha-phenoxybutyric acids.

Chemical	Rate lb/A	Percentage reduction in green weight yield									
		W. clover	R. clover	S. clover	Alfalfa	Flax	Buck-wheat	Soy-beans	Bras-sica	Oats	Corn
2-(2,4-DB)	¼	72	56	53	68	11	26	31	28	0	2
	½	89	69	78	79	11	39	42	23	6	20
	1	92	89	92	86	37	37	59	44	7	23
	Av.	84	68	74	78	20	34	44	32	4	15
2-(MCPB)	¼	95	51	90	78	21	33	50	23	13	8
	½	97	65	92	91	42	54	70	34	9	18
	1	99	69	98	94	46	50	72	52	6	0
	Av.	97	62	93	88	36	46	64	36	9	9
2-(2,4,5-TB)	¼	98	69	84	71	66	35	51	25	8	1
	½	97	87	95	82	88	54	17	27	15	0
	1	99	84	97	84	92	65	76	60	3	22
	Av.	98	80	92	79	82	51	48	41	9	8
2-(3,4-DB)	¼	37	0	16	0	22	38	32	20	10	0
	½	24	19	30	25	9	40	50	37	9	7
	1	51	30	55	18	55	46	64	38	16	11
	Av.	37	16	34	14	29	41	49	32	12	6
2-(4-CPB)	¼	3	0	0	9	0	25	11	35	7	5
	½	19	20	10	6	0	32	42	19	0	4
	1	31	23	30	38	12	59	55	34	0	12
	Av.	18	14	13	18	4	39	36	27	2	7
2,4-D	¼	77	90	88	90	47	51	49	92	12	1
	½	91	98	92	94	62	77	54	92	19	0
	1	99	98	97	96	88	97	82	94	6	16
	Av.	89	95	92	93	66	75	62	93	12	6

Table 5. The effect of five ring substitutions on the selectivity of several gamma-phenoxybutyric acids.

Chemical	Rate lb/A	Percentage reduction in green weight yield									
		W. clover	R. clover	S. clover	Alfalfa	Flax	Buck-wheat	Soy-beans	Bras-sica	Oats	Corn
4-(2,4-DB)	¼	14	11	52	28	0	51	27	78	6	0
	½	25	0	81	13	55	85	39	81	0	0
	1	0	15	91	7	80	91	52	78	0	24
	Av.	13	9	75	16	45	76	39	79	2	8
4-(MCPB)	¼	6	9	63	18	0	39	31	68	18	0
	½	0	3	81	30	0	61	54	73	0	10
	1	11	19	88	65	0	69	54	62	11	0
	Av.	5	10	77	38	0	56	46	68	10	3
4-(2,4,5-TB)	¼	0	6	3	11	0	8	14	31	10	2
	½	0	0	36	18	12	21	14	24	0	0
	1	0	12	48	13	49	39	9	47	0	15
	Av.	0	6	29	14	20	23	12	34	3	6
4-(3,4-DB)	¼	37	0	16	0	22	38	32	20	10	0
	½	24	19	30	25	9	40	50	37	9	7
	1	51	30	55	18	55	46	64	38	16	11
	Av.	37	16	34	14	29	41	49	32	12	6
4-(4-CPB)	¼	19	38	0	17	11	16	48	57	19	0
	½	16	51	16	31	34	24	65	62	9	3
	1	13	67	25	52	36	21	65	78	20	0
	Av.	16	52	14	33	27	20	59	66	16	1
2,4-D	¼	77	90	88	90	47	51	49	92	12	1
	½	91	98	92	94	62	77	54	92	19	0
	1	99	98	97	96	88	97	82	94	6	16
	Av.	89	95	92	93	66	75	62	93	12	6

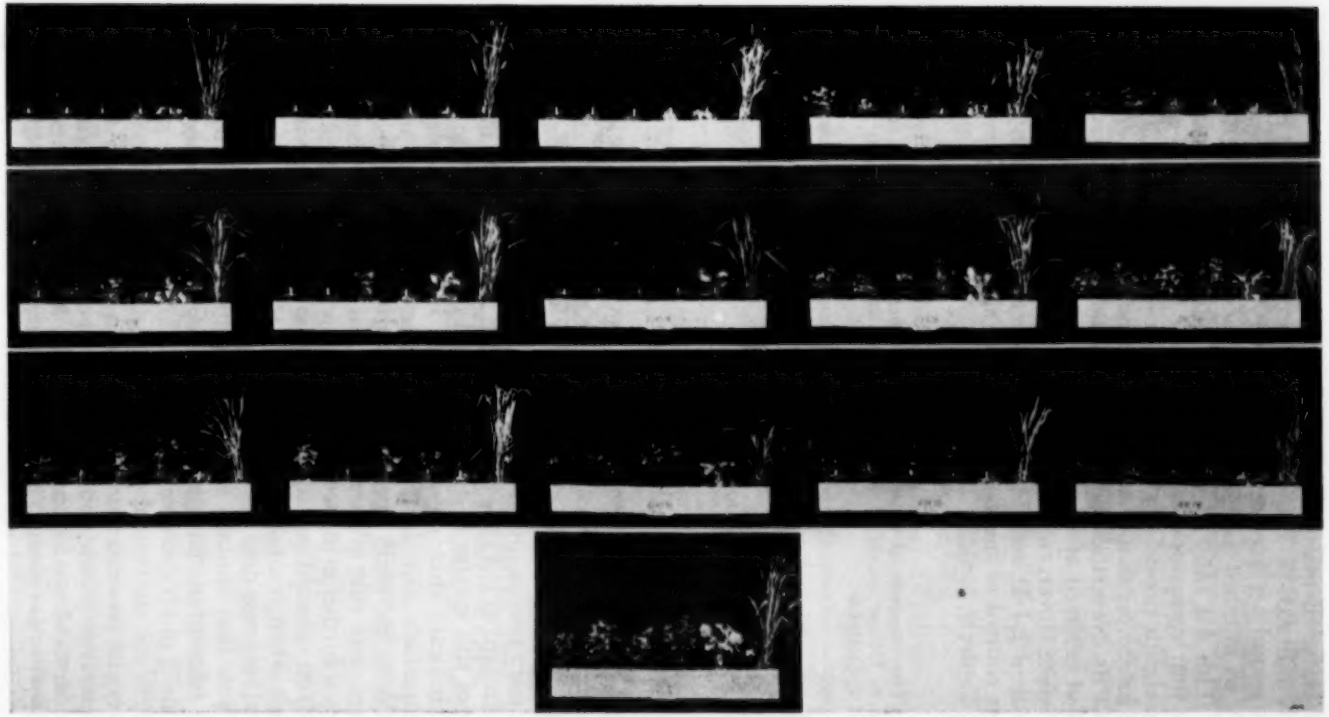


Figure 1. The effect of 15 phenoxyalkylcarboxylic acids at one-half pound per acre as a foliage spray on (left to right—see check) white clover, sweetclover, redclover, alfalfa, *Brassica napus* and oats.
Top row, L to R: 2,4–D, MCPA, 2,4,5–T, 3,4–DA, 4–CPA
Center Row, L to R: 2–(2,4–DB), 2–(MCPB), 2–(2,4,5–TB), 2–(3,4–DB), 2–(4–CPB)
Bottom row, L to R: 4–(2,4–DB), 4–(MCPB), 4–(2,4,5–TB), 4–(3,4–DB), 4–(4–CPB)

The response of mustard to 2,4–D, MCPA, 4–(2,4–DB), and 4–(MCPB) is indicated in Tables 6 and 7. The data in Table 6 indicate that 1/64 pound per acre of 2,4–D or MCPA was approximately as inhibitory to mustard as 1/8 pound per acre of 4–(2,4–DB) or 4–(MCPB). This 8:1 ratio of activity was approximately maintained when the four compounds were applied at higher rates of application. One-eighth pound per acre of 2,4–D or MCPA was approximately as inhibitory to mustard as one pound per acre of 4–(2,4–DB) or 4–(MCPB). Nevertheless, 4–(2,4–DB) and 4–(MCPB) gave complete kill of mustard at rates of application which had little or no effect on white clover, red clover, alfalfa, oats, or corn, while rates of application of 2,4–D and MCPA which were high enough to give equivalent control of mustard resulted in significant injury to the legumes (Tables 2, 5, 6).

Table 6. The response of mustard *(Brassica kaber)* at the 4 inch stage of growth to foliage sprays of four phenoxyalkylcarboxylic acids at several rates of application.

Rate of application lb/A	Percentage reduction in green weight yield			
	2,4–D	MCPA	4–(2,4–DB)	4–(MCPB)
1/128	62	40	35	35
1/64	68	65	29	36
1/32	91	76	39	36
1/16	88	89	48	44
1/8	91	92	63	59
1/4	98	100	76	78
1/2	99	100	77	82
1	100	100	89	94
Check	0	0	0	0

Preliminary results suggested the importance of stage of development of mustard at the time of treatment in relation to the degree of tolerance of this species to 4–(2,4–DB) and (4–MCPB). The data in Table 7 indicate that mustard becomes increasingly tolerant to these compounds with increasing age. Greater tolerance to 2,4–D and MCPA as the plant approaches maturity may be noted at the lower rates, but this greater tolerance was masked at the higher rates. This is further evidence of the lower activity of 4–(2,4–DB) and 4–(MCPB) on mustard and suggests the importance of applying these compounds when mustard is in the early seedling stage of growth. Additional response data obtained under greenhouse and field conditions indicate that mustard is most susceptible in the seedling stages and most tolerant at the pre-bud stage.

Field Studies

The pre- and post-emergence applications with the phenoxyacetic, alpha-phenoxypropionic and gamma-phenoxybutyric acids on 25 test plants under field conditions at Beltsville, Maryland confirmed the greenhouse results reported herein. The data from these field studies have been summarized elsewhere (13).

Table 7. The effect of several phenoxyalkylcarboxylic acids applied at different rates of application as foliage sprays to mustard *(Brassica kaber)* at three stages of growth.

Chemical	Rate lb/A	Percentage reduction in green weight when treated at three heights		
		3 inches	6 inches	12 inches
2,4-D	1/16	99	89	61
MCPA	1/16	97	78	44
4-(2,4-DB)	1/16	29	28	12
4-(MCPB)	1/16	18	23	22
2,4-D	1/8	100	100	83
MCPA	1/8	100	91	46
4-(2,4-DB)	1/8	70	28	23
4-(MCPB)	1/8	95	34	9
2,4-D	1/4	100	100	90
MCPA	1/4	100	95	70
4-(2,4-DB)	1/4	91	73	36
4-(MCPB)	1/4	96	40	13
2,4-D	1/2	100	100	91
MCPA	1/2	100	100	100
4-(2,4-DB)	1/2	96	74	39
4-(MCPB)	1/2	99	43	25
2,4-D	1	100	100	100
MCPA	1	100	100	100
4-(2,4-DB)	1	100	90	32
4-(MCPB)	1	98	84	39
2,4-D	2	100	100	100
MCPA	2	100	100	100
4-(2,4-DB)	2	100	98	42
4-(MCPB)	2	100	73	72
Check		0	0	0

A comparison of 4-(2,4-DB) and 4-(MCPB) with 2,4-D and MCPA as pre-emergence treatments under field conditions indicates striking differences in herbicidal activity (Table 8). The possibility

Table 8. A comparison of the selective herbicidal properties of several phenoxy compounds applied as pre-emergence sprays.

Chemicals applied at 2 lb/A	Percentage kill						
	Corn	Soybeans	Cotton	Peanuts	Sorghum	BL weeds*	Grasses
2,4-D	0	80	95	20	70	95	90
4-(2,4-DB)	0	20	10	0	20	95	90
MCPA	0	80	95	20	70	95	90
4-(MCPB)	10	20	20	0	10	95	95
Check	0	0	0	0	0	0	0

*BL = broadleaved weeds.

exists that soil microorganisms may degrade the gamma-phenoxybutyric acids in much the same way as enzymes do in plants. There is also the strong possibility that these compounds are degraded by enzymes in embryonic plants during the process of germination and emergence, as well as by soil microorganisms. However, again the structure and other physical properties of the compounds and their possible activity *per se* undoubtedly affect their selective properties as pre-emergence treatments.

DISCUSSION

Selectivity and Specificity

A review of Figure 1 and the data in Figures 2a and2b indicate that all the compounds studied in these investigations possessed selective herbicidal activity.

The selective herbicidal activity and specificity of the phenoxyacetic and alpha-phenoxypropionic acids were quite similar. The differences in activity of these two groups were mostly in level of activity rather than in kind or specificity of action. On the test species

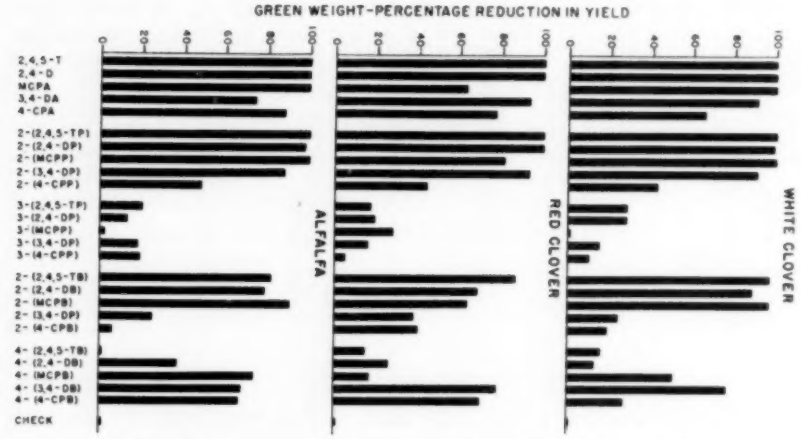


Figure 2a. The effect of several phenoxyalkylcarboxylic acids at ½ lb. per acre on three species.

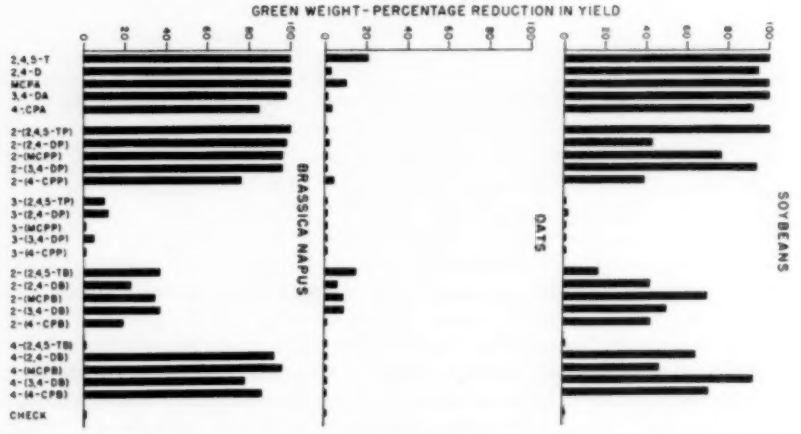


Figure 2b. The effect of several phenoxyalkylcarboxylic acids at ½ lb. per acre on three species.

included in these studies, the phenoxyacetic acids in general possessed a slightly higher average level of inhibitory activity than the alpha-phenoxypropionic acids (Figures 2a and 2b).

The beta-phenoxypropionic acids were the least active of the compounds studied.

The selective herbicidal activity of the alpha- and gamma-phenoxybutyric acids was quite different. The selectivity and specificity of the alpha-phenoxybutyric acids more closely paralleled that of the phenoxyacetic and alpha-phenoxypropionic acids (Figures 2a and 2b). There were some exceptions to this generalization, especially the lower activity of the alpha-phenoxybutyric acids on brassica. This latter difference was striking enough to suggest the need for an investigation of the alpha-phenoxybutyric acids for weed control in crops of the genus *Brassica* (Figures 2a and 2b).

The specific action of some of these compounds may be illustrated by reviewing the data in Figure 3. Flax shows considerable tolerance to MCPA, less tolerance to 2–(MCPB), but very high tolerance to 4–(MCPB). The very striking differential effects of the phenoxyacetic, and alpha- and gamma-phenoxybutyric acids on flax indicate the necessity of carefully assaying the activity of chemicals on many

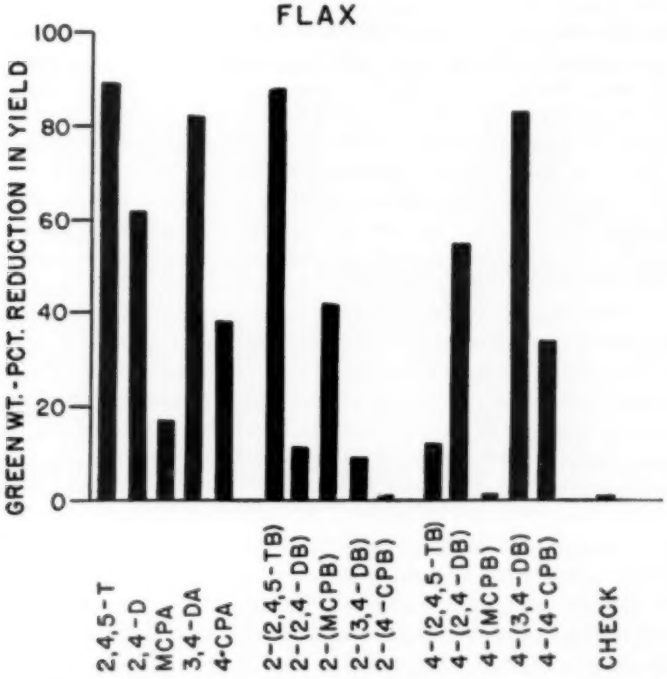


Figure 3. The effect of several phenoxyalkylcarboxylic acids at ½ lb. per acre on flax.

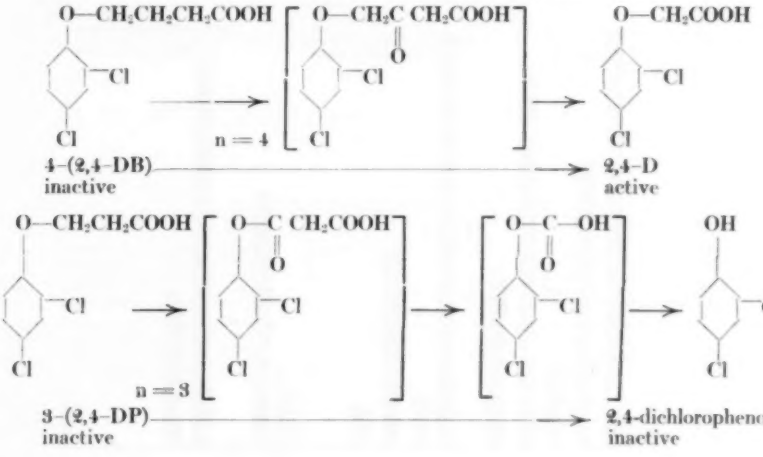
species in order to determine accurately their selective properties and potential use.

The herbicidal specificity of the gamma-phenoxybutyric acids was quite striking and suggests the potential practical usefulness of these compounds for the control of specific weeds in crops that are not tolerant to the phenoxyacetic or alpha-phenoxypropionic acids (Figures 2a and 2b). These preliminary findings support the work of others who have investigated 4–(MCPB) for the control of weeds in legumes (1).

Relationship between Structure and Herbicidal Selectivity and Specificity

The studies reported herein lend support to the theory first proposed by Synerholm and Zimmerman (14) and later confirmed by Wain and Wightman (18) that certain enzyme systems in certain plants may degrade omega-phenoxyalkylcarboxylic acids with an even number of carbon atoms in the side chain to the herbicidally active acetic acids, while members with an odd number of carbon atoms in the side chain are degraded to the herbicidally inactive phenol.

The process may be represented as follows (14):



Thus, except for contact localized activity, the beta-phenoxypropionic acids with an odd number of carbon atoms were inactive while the gamma-phenoxybutyric acids with an even number of carbon atoms in the side chain are degraded to the active acetic acids.

The results reported herein also lend support to the theories that have been developed on the structural requirements for activity in the phenoxyalkylcarboxylic acids (6, 8, 9).

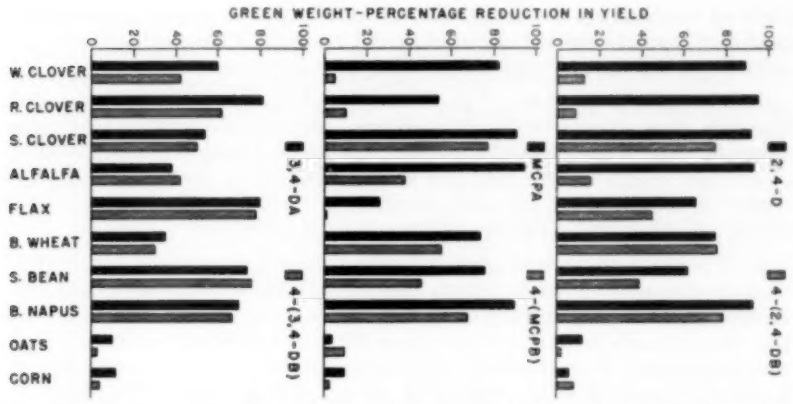


Figure 4. A comparison of the effect of six phenoxy compounds on several species. Yield reductions are the means of ¼, ½, and 1 lb. per acre rates of application.

Although the results of these studies lend some support to evidence presented by others (14, 18) on the role that enzymes may play in the selective herbicidal action of the omega-phenoxyalkylcarboxylic acids, the data in Figure 4 also suggest that the mechanism involved is not simple. The significant effect of ring substitution is clearly evident. The herbicidal effects of 4–(3,4–DB) on the test species in this experiment were unlike those of 4–(2,4–DB) and 4–(MCPB). For instance, the effects of 4–(3,4–DB) on white clover, red clover, and alfalfa were very similar to those of 3,4–DA, while the activity of 4–(2,4–DB) was quite unlike the activity of 2,4–D on the same species. The effect of the interaction of ring substitutions and side chain substitutions on the selectivity of these compounds is strikingly evident (Figures 2a, 2b, 3, and 4). Enzyme systems are undoubtedly important in the selective action of the gamma-phenoxybutyric acids. However, a number of other factors such as penetration and translocation may also be involved in the selective action of these compounds.

It must be stressed that if a chemical is to be beta-oxidized within a plant, it must possess (1) the necessary physical properties to enhance its penetration into plants, (2) the proper structural configuration to facilitate its translocation in the plant to the loci of activity, (3) a structure which will enable it to become adsorbed and correctly orientated at the surface of the enzymes. (4) a side chain structure which is subject to beta-oxidation, and (5) a ring structure which does not interfere with beta-oxidation of the side chain.

SUMMARY

These preliminary investigations included a study of the selective herbicidal properties of 25 variously substituted phenoxyalkylcarboxylic acids. The chemically pure acids were evaluated for their pre- and post-emergence selective herbicidal properties at several

rates of application on more than 25 plant species under greenhouse and field conditions at Beltsville, Maryland. The preliminary results reported herein may be summarized as follows:

1. The results of these experiments lend some support to current theories that plants with the proper enzymatic constitution may degrade omega-phenoxyalkylcarboxylic acids with an even number of carbon atoms in the side chain to herbicidally active derivatives, while members with an odd number of carbon atoms in the side chain are degraded to herbicidally inactive metabolic products.

2. The data presented also indicate that the structural configuration of chemicals greatly affects their selective herbicidal properties. In the gamma-phenoxybutyric acid series, leaving the 2-position of the ring unsubstituted greatly changed the selectivity of this group of compounds. For example, the selectivity of the 3,4–dichloro and 4–chloro derivatives as compared to the 2,4–dichloro, 2–methyl–4–chloro, and 2,4,5–trichloro derivatives was significantly different.

3. These studies indicate clearly the need for using a wide variety of intact plants in order to clearly delineate the selective herbicidal properties of active compounds. The use of tissue and *in vitro* type evaluation methods does not permit full expression of the interaction of structural configuration with penetration, absorption, translocation, and mode of action, which are influenced by environmental conditions and greatly affect the selective herbicidal properties of compounds.

4. The response data suggest the potential use of 4–(2,4–DB), 4–(MCPB) and 4–(2,4,5–TB) for the post-emergence control of broadleaved weeds in (a) cereals underseeded with certain forage legumes, (b) the establishment of pure stands of forage legumes, (c) forage legume seed-production fields, (d) flax, (e) tolerant crops such as corn or rice grown in the vicinity of crops highly susceptible to the phenoxyacetic and alpha-phenoxypropionic acids, such as cotton, grapes, etc., and (f) in certain other weed-crop situations.

5. The alpha-phenoxybutyric acids 2–(2,4–DB), 2–(MCPB), and 2–(2,4,5–TB) showed high herbicidal activity on several of the test species and low activity on brassica. These results suggest the need for investigating these compounds for the control of weeds in crops of the genus *Brassica*.

6. In the field studies, pre-emergence treatments with 4–(2,4–DB) and 4–(MCPB) gave good control of a number of annual broadleaved weeds and annual grasses with much less injury to corn, cotton, soybeans, peanuts, and sorghum than occurred from pre-emergence treatments with 2,4–D and MCPA.

7. The influence of ring and side chain substitutions on the effects of the phenoxyalkylcarboxylic acids on plants and their possible metabolism in plants, makes it essential to obtain more information about the possible enzyme systems involved before a clear understanding of the mechanism of action of these compounds is possible.

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The Phytotoxicity of Four Phenylurea Herbicides in Soil[1]

T. J. Sheets[2] and A. S. Crafts[3]

The toxicity of the substituted urea herbicides may persist in the soil for considerable periods following treatment. Consequently, they have been used extensively as pre-emergence and post-emergence herbicides and as soil sterilants. In the drier regions of the western states injury to cereals may occur when they are seeded in the fall following cotton which has been treated with the substituted ureas to control weeds. Because of the nature of these compounds and because of their rapid acceptance as herbicides, much interest has developed in relation to their breakdown in the soil.

Loustalot, et al. (9) stated that certain factors favorable for microbial activity, such as warm temperature, adequate moisture, and the presence of organic matter, hastened the decomposition of 3–(*p*-chlorophenyl)–1,1–dimethylurea (monuron). Their results showed that toxicity from monuron was lost more rapidly when adequate water was supplied. Monuron at a rate corresponding to five pounds per acre disappeared in two weeks in soil maintained at field capacity whereas in air dry soil at least 10 weeks were required for its breakdown. In soil containing 20 percent moisture four weeks were required. Further, monuron toxicity persisted longer at 10°C than at room temperature (20°C to 30°C) or 45°C. Ogle and Warren (10) demonstrated that an increase in temperature enhanced the loss of monuron in a muck soil and proposed that biological activity was responsible. That microorganisms enhance the breakdown of monuron was suggested by Hill, et al. (7) from results of studies comparing the effect of sterilized and unsterilized soil on residual activity. These workers reported that a soil bacterium of the *Pseudomonas* group was capable of using monuron as a sole source of carbon. They indicated further that monuron may be oxidized by other soil microorganisms if certain accessory growth factors are present. They stated that in agricultural soils both the microorganisms and the growth factors usually occur. From the above studies it was also suggested that microorganisms are active in the detoxification of 3–(3,4–dichlorophenyl)–1,1–dimethylurea (diuron).

The studies reported here were initiated (1) to investigate the effect of autoclaved and non-autoclaved soil on the breakdown of four substituted urea herbicides, (2) to compare the breakdown of the four herbicides in continuously moist soil and in soil which was moist every other month, and (3) to compare their toxicity in aqueous solutions with the initial toxicity in one soil type.

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[1]Cooperative investigations of the Field Crops Research Branch, ARS, USDA and the Calif. Agri. Exp. Sta.

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METHODS AND MATERIALS

A procedure for determining the toxicity of herbicides in soils by biological means was adopted for these studies. The method was described in 1935 and 1936 by Crafts (1, 3) and has been used extensively since that time (2, 4, 5, 6, 11). Four substituted urea herbicides[4], 3–(*p*-chlorophenyl)–1,1–dimethylurea (monuron), 3–(3,4–dichlorophenyl)–1,1–dimethylurea (diuron), 3–(3,4–dichlorophenyl)–1–methylurea (DMU), and 3–(phenyl)–1,1–dimethylurea (fenuron), were tested in the greenhouse with respect to their initial and residual activity in the soil. Each material was thoroughly mixed with autoclaved (15 psi for 3 hours, 250°F) and non-autoclaved Yolo clay loam at six concentrations ranging from 0.0 to 8.0 ppmw of air dry soil. The experiment was divided further into two parts: (1) soil cropped continuously and therefore moist continuously and (2) soil cropped during alternate months with one-month dry periods between crops. Each culture consisted of 500 grams of treated air dry soil contained in No. 2 metal cans. There were three replications.

Following treatment of the soil 13 Kanota oat seeds were planted in each can. In all cases the indicator plants were grown for approximately 28 days. At the end of that period the plants were harvested, and the fresh weights in grams of the growth above the soil level were used as a measure of toxicity. Following the first harvest the soil in the continuously cropped cultures was pulverized and crop residues were returned to the containers. The cultures were watered to field capacity and reseeded to oats. The plants were again allowed to grow for 28 days and the data recorded. During this period the alternate group was left dry and undisturbed.

Following the second harvest all treatments (both continuous and alternate) were reprocessed and seeded. Again the crop residues were returned to the cultures. This sequence of cropping and harvesting was continued for 11 months. Special efforts were made during the cultural operations to prevent contamination of the autoclaved cultures with non-autoclaved soil. There are indications, however, that some contamination of undetermined source did occur during the later stages of the study.

An experiment was conducted to determine the toxic level of the same materials in nutrient culture. Kanota oats were germinated in autoclaved sand and, when approximately eight centimeters high, were transferred to treated Hoagland's solution (8). The oats were grown for approximately three weeks in culture solutions containing the four herbicides at concentrations ranging from 0.001 to 3.125 ppmw. Fresh weights of tops taken three weeks following transfer, were used to determine the critical level of the materials in solution.

RESULTS AND DISCUSSION

In the soil studies the weights of growth on the checks and on the sub-lethal treated cultures varied from month to month. These

[4]Experimental samples supplied by E. I. DuPont de Nemours and Company, Wilmington 98, Delaware.

variations were due, at least partially, to differences in the amount of incident sunlight and also to other variations of growth conditions in the greenhouse. In addition there was a general decrease in yields on cultures which supported crops month after month. The decline in most cases began with the second cropping. This was not a consistant decrease because of the month to month variations. Yields tended to level out after four or five months and, thereafter, varied with light and other greenhouse conditions. Yields eight and eleven months after treatment on controls and on continuously moist, non-autoclaved cultures were lower than those of the immediately preceding months (Table 1 and Figure 2). These declines were not caused by herbicide toxicity but are examples of the monthly variations and the general decline following months of heavy yields.

In Figure 1 the fresh weights of oats for the first cropping are plotted against concentrations of the four chemicals in ppm of the air dry soil. From these curves it can be seen (1) that there is little or no difference in the initial toxicity of monuron and fenuron in Yolo clay loam, (2) that DMU is much less phytotoxic and (3) that diuron toxicity is intermediate in this soil type.

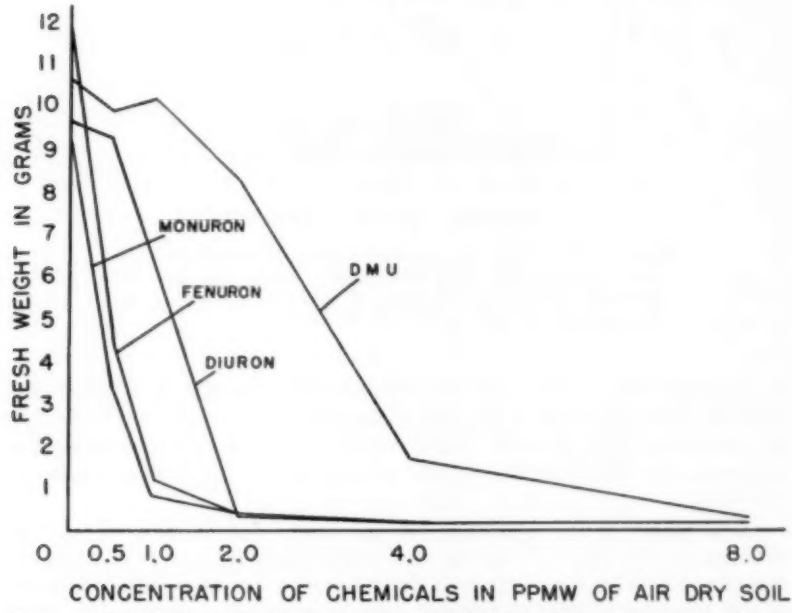


Figure 1. The initial toxicity of the four herbicides in Yolo clay loam as shown by the growth of oats above the soil level.

Curves depicting the toxicity of 2.0 ppm of monuron with respect to time in autoclaved and non-autoclaved soil and in continuously and alternately moist soil are shown in Figure 2. All toxicity from 2.0 ppm of monuron disappeared by seven months after treatment

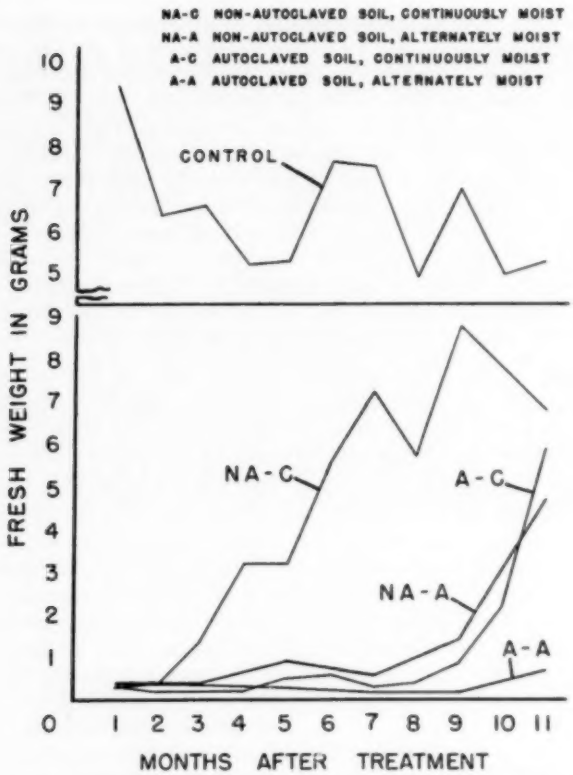


Figure 2. The effect of autoclaved and non-autoclaved soil and continuously and alternately moist soil on the residual toxicity of 2.0 ppm of monuron as shown by the growth of oats above the soil level.

in continuously moist, non-autoclaved soil, whereas at least eleven months were required if the soil was autoclaved or was moist during the alternate months only. Thus non-autoclaved soil and moisture, adequate for the growth of oats, enhanced the loss of monuron in this soil.

Data showing the influence of the four soil treatments on the toxicity of 4.0 ppm of fenuron and DMU and 2.0 ppm of diuron are presented in Table 1. Although there were variations in the responses of the four herbicides to the soil and moisture treatments, the same general conclusions hold: Toxocity was lost more rapidly (1) in non-autoclaved soil than in soil which was autoclaved initally and (2) in soil which was moist continuously as opposed to soil which dried one month between croppings.

These results suggest that microorganisms or some product of microbial activity, which is inactivated by autoclaving, are of para-

Table 1. The influence of four soil treatments on the toxicity of 4.0 ppm of fenuron and DMU and 2.0 ppm of diuron as shown by the growth of Kanota oats. The values are fresh weights of tops in grams per culture.

Cropping number (months)	Fenuron 4 ppm				Diuron 2 ppm				DMU 4 ppm				Controls	
	A–A[1]	A–C	NA–A	NA–C	A–A	A–C	NA–A	NA–C	A–A	A–C	NA–A	NA–C	Alternately moist	Continuously moist
1	0.2	0.3	0.2	0.2	0.4	0.2	0.3	0.3	2.6	1.5	1.0	1.6	10.4	10.2
2	—	0.2	—	0.3	—	0.6	—	0.6	—	0.7	—	1.0	—	7.3
3	0.2	0.1	0.4	1.8	0.3	1.0	1.4	3.5	1.4	1.2	1.1	2.0	7.4	6.5
4	—	0.2	—	4.2	—	1.6	—	5.0	—	1.8	—	2.9	—	5.9
5	0.2	0.2	1.2	5.4	1.5	2.2	2.6	5.0	1.9	2.5	0.6	5.0	5.6	5.3
6	—	0.3	—	8.3	—	3.6	—	8.3	—	2.8	—	8.7	—	8.0
7	0.2	0.2	2.1	10.7	0.8	2.2	1.6	7.6	0.9	2.2	0.6	9.3	7.8	7.0
8	—	0.3	—	6.1	—	4.5	—	5.1	—	4.3	—	5.5	—	4.4
9	0.2	0.5	4.5	9.9	1.2	6.0	6.6	7.6	1.6	7.0	3.3	9.1	7.0	7.1
10	—	1.3	—	8.3	—	5.9	—	5.1	—	7.4	—	6.6	—	5.3
11	0.5	5.4	7.8	6.6	5.7	7.2	7.4	5.1	4.7	8.2	6.6	4.6	5.4	5.1

[1]A–A—autoclaved soil, alternately moist.
A–C—autoclaved soil, continuously moist.
NA–A—non-autoclaved soil, alternately moist.
NA–C—non-autoclaved soil, continuously moist.

mount importance in the inactivation of these herbicides. This is in agreement with results of other workers who have shown that loss of toxicity from monuron (7, 9, 10) and diuron (7) is enhanced by factors favoring microbial activity. These studies show also that fenuron and DMU are similar in behavior to monuron and diuron in this respect. The degree to which the several treatments affect the rate of breakdown may vary within this group of herbicides.

Although the experiment was not designed for close comparisons between chemicals, certain results are clearly evident. The order of the four chemicals with respect to toxicity in continuously moist, autoclaved soil changed only slightly between the beginning of the experiment and the end of the tenth month (Table 2). In continuously moist, non-autoclaved soil the order of toxicity shifted. Fenuron, one of the most toxic initially, was least toxic by the end of the fifth month in non-autoclaved soil. If the difference between autoclaved and non-autoclaved soil is related to decomposition by

Table 2. The effect of autoclaved and non-autoclaved soil on the relative rates of breakdown of four herbicides.

Months after treatment	Treatment	Order of decreasing toxicity
1	Autoclaved	monuron ≅ fenuron diuron DMU
5	Autoclaved	monuron fenuron diuron DMU
10	Autoclaved	monuron fenuron ≅ diuron DMU
1	Non-autoclaved	monuron ≅ fenuron diuron DMU
5	Non-autoclaved	monuron diuron DMU fenuron
10	Non-autoclaved	monuron diuron DMU fenuron

microorganisms, this last observation suggests that the rates of microbial inactivation vary among these materials and that fenuron is affected most readily. Two postulations may be offered as possible reasons for the more rapid microbial inactivation of fenuron: (1) because of its greater solubility and probable lower degree of adsorption to the colloidal components of the soil, fenuron may be more available for microbial degradation than the other three herbicides or (2) the absence of the chlorine atom on the phenyl ring of the fenuron molecule may account for the rapid microbial degradation; the other three compounds each contain at least one chlorine atom on the phenyl ring and may be more resistant to this type of breakdown as a result of this substitution.

Microorganisms capable of inactivating these herbicides are probably present in most soils (7) and are supposedly active when environmental factors are favorable. Under the arid conditions of the western states, breakdown of these materials may be greatly retarded because of prolonged dry periods. Figure 2 shows that under the alternate cropping method in this soil type 2.0 ppm of monuron were still toxic to oats after 9 months and probably even 11 months.

In Table 3 the initial toxicity of the four herbicides in Yolo clay loam is compared with toxicity in nutrient solution. The oats were

grown continuously for three weeks in the nutrient solution and for four weeks in the treated soil. The values in the table represent the amounts of the chemicals in the cultures required to reduce the fresh weight of oats by 50 percent. These data show that DMU and diuron were most toxic in nutrient solution. However, in soil monuron and fenuron were most toxic initially.

The fifth column in Table 3 is the numerical value of the ratio column 4/column 3; i.e., the amount of chemical required in Yolo clay loam to reduce growth by 50 percent divided by the amount of chemical required in nutrient solution to reduce growth 50 percent.

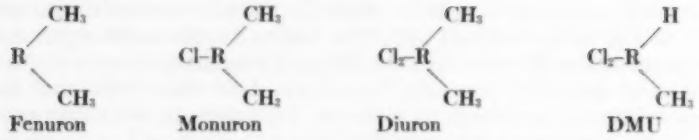
Table 3. **Comparisons of the toxicities to oats of the substituted ureas in nutrient solution and in Yolo clay loam.**

Chemical	Solubility in water ppmw	Grams of chemicals ($\times 10^{-6}$) required in 400 ml of nutrient solution and in 500 gm of air dry soil to reduce growth 50 percent		Ratio $\frac{\text{Amount in soil}}{\text{Amount in nut. sol.}}$
		Nutrient solution	Yolo clay loam	
DMU.....	74	1.8	130	72
Diuron.....	42	1.9	53	28
Monuron...	230	3.0	20	7
Fenuron....	2900	12.1	23	2

All of these values are greater than one, showing that more of the chemicals are required in the soil than in nutrient solution. Indeed 72 times as much DMU was required; 28 times as much diuron; 7 times as much monuron; and 2 times as much fenuron. These comparisons indicate that the capacity of the soil to adsorb these compounds, or in some other way render them inactive as herbicides, varies tremendously. If the water in the soil is considered as the medium in which the herbicides are dissolved, then the apparent magnitude of the soil effects is greatly increased. Since this soil contains approximately 20 percent moisture at field capacity, the amount of chemical present in the soil, in terms of the volume of soil solution, is approximately five times as great as the concentration based on the weight of air dry soil. It should be mentioned that the order of toxicity of these herbicides varies somewhat in different soils. Evidence for this will be given in a later publication.

It is evident from Table 3 and Figure 1 that there is little or no difference in initial toxicity of monuron and fenuron in Yolo clay loam. The toxicity in culture solution (inherent toxicity) is increased almost fourfold by the single chlorine substitution on the phenyl ring. Substitution of a second chlorine further enhances toxicity in culture solution. Toxicity in Yolo clay loam follows roughly an inverse pattern, probably because of fixation by the soil colloids. Proceeding to the ratio of toxicity in the soil to toxicity in culture solution, a series of values that reflect the strong detoxifying capacity of the soil, we find the inverse relation greatly accentuated.

Because of the electrophilic nature of the chlorine atom, it seems evident that the shift in electron balance in traversing the series



must have a profound effect on the adsorption relations between the molecules and soil colloids. The removal of one methyl group decreases toxicity in the soil over twofold but has no effect on toxicity in nutrient solution. From this it might be deduced that the role of the methyl substitution in toxicity relationships is adsorption, whereas the phenyl and chlorophenyl substitutions are the parts of the molecules most directly involved in the reactivity of the compounds with cellular constituents, as well as being active in the adsorptive relationships. Solubility is a complicating factor in this situation, and additional work will be required before a final evaluation of all factors controlling toxicity can be made.

SUMMARY

The initial and residual toxicities of four substituted urea herbicides, monuron, diuron, fenuron, and DMU, were investigated in one soil type. The effect of two variables on the residual toxicity was studied: (1) autoclaved versus non-autoclaved soil and (2) continuously moist soil versus soil which was dry every other month. The initial toxic level of the herbicides in soil was compared with their toxicity in nutrient solution. The results are summarized as follows:

Toxicity of all four compounds was lost more rapidly in non-autoclaved soil than in soil which was autoclaved initially.

Toxicity disappeared more rapidly in continuously moist soil as opposed to soil which was dry every other month.

These results suggest that microorganisms, or products of microbial activity, are important in the breakdown of these herbicides.

Of the four herbicides fenuron was inactivated most rapidly in non-autoclaved soil, but its persistence in autoclaved soil approached that of the other three.

Diuron and DMU were most toxic in nutrient solution, but in soil monuron and fenuron were most toxic initially. Hence, the capacity of the soil to adsorb these compounds, or in some other way render them inactive as herbicides, varies greatly.

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A Spectrophotometric Method for the Determination of Several Chlorinated Phenoxyacetic Acids[1]

K. P. Dorschner and K. P. Buchholtz[2]

Studies with plant growth-regulators are severely handicapped unless methods are available for quantitative determinations of these chemicals. Beginning with the classical work of Went (12), several techniques have been developed to obtain a quantitative measure of plant growth-regulating chemicals. Brown and Weintraub (3), Hitchcock and Zimmerman (6) and Frankton (4) have discussed the use of biological assays as quantitative tests for various hormone-type chemicals. Thus far, the only biological methods developed beyond the semi-quantitative stage are those depending on cell elongation in shoots, inhibition or elongation of roots, and the stimulation of ovary development.

Recently, more rapid chemical tests have been proposed. Stroud (10) and Ketelaar and co-workers (7) have described chemical tests for the detection of 2,4–dichlorophenoxyacetic acid (2,4–D), and for 2,4–D and 2–methyl–4–chlorophenoxyacetic acid (MCPA) respectively. Luckwill (9), Bennet-Clark et al. (2) and Vlitos and Meudt (11) have proposed the use of paper and partition chromotography for the quantitative measurement and qualitative detection of plant growth-regulating compounds. Spectrophotometric techniques for the quantitative detection of 2,4–D have been described by Bandurski (1) and LeTourneau and Krog (8). A quantitative spectrophotometric method for the determination of MCPA has been described by Grabe (5).

The analytical method described by Bandurski (1) has established an ultra-violet light absorption maximum at 2835 angstroms, and an extinction coefficient of 9.0, for purified 2,4–D in aqueous solvent. An additional extinction peak was reported for 2,4–D in ether solvent. The present study was made in an attempt to expand this technique so as to include aqueous solutions of the sodium and amine salts of 2,4–D and several other chlorinated phenoxyacetic acid plant growth-regulating chemicals.

Materials and Methods

The absorption spectra of eight plant growth-regulating chemicals in aqueous solutions were determined with a model DU Beckman Quartz Spectrophotometer using a hydrogen discharge tube as the

[1]Contribution from the Dept. of Agronomy, Wisconsin Agr. Exp. Sta., Madison, Wisconsin. Published with the approval of the Director of the Wisconsin Agr. Exp. Sta. Part of a thesis submitted by the senior author to the Graduate School of the University of Wisconsin in partial fulfillment of the requirements for the Ph.D. degree.

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light source and 10 x 10 x 40 mm. fused silica sample cells. Chemicals characterized in this way were of commercial grade. They included 2,4–dichlorophenoxyacetic acid (2,4–D); the sodium salt of 2,4–dichlorophenoxyacetic acid (2,4–DNa); a mixture of isopropyl and ethanolamine salts of 2–methyl–4–chlorophenoxyacetic acid (MCPA); and the triethanolamine salts of 2,4–dichlorophenoxyacetic acid (2,4–DA), 2,5–dichlorophenoxyacetic acid (2,5–DA), 3,4–dichlorophenoxyacetic acid (3,4–DA), 4–chlorophenoxyacetic acid (4–CPA), and 2,4,5–trichlorophenoxyacetic acid (2,4,5–T).

Duplicate samples of each chemical were prepared at known concentrations in distilled water on an acid equivalent basis. Small aliquots of each sample were then used to determine the spectrophotometric absorption peak for each compound. The ultraviolet light wave band found most efficient in absorbency for each chemical was then used to measure a series of dilutions of each stock solution in preparation of the linear or working-curves.

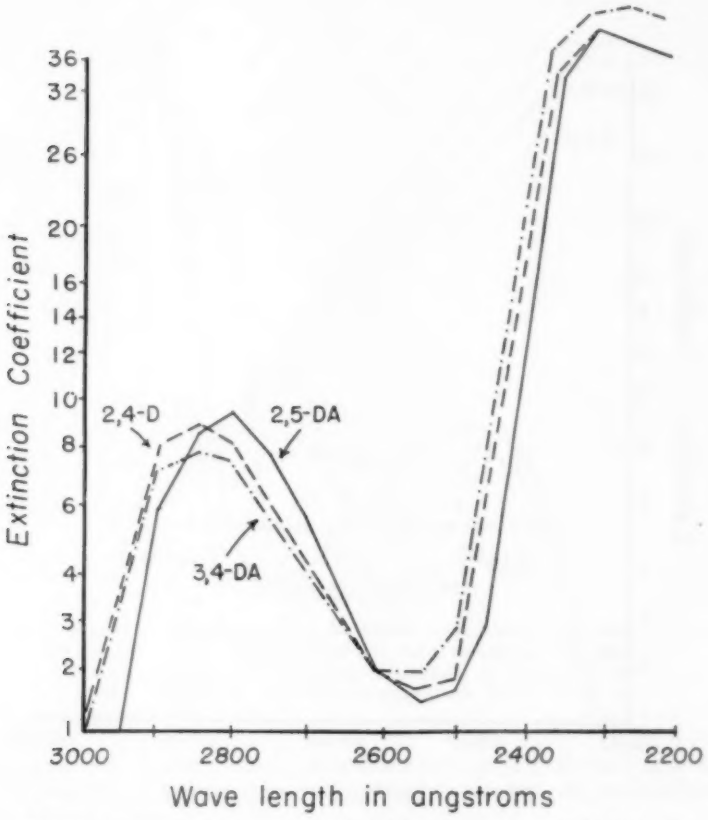

Figure 1. Absorption spectra of 2,4–D, 3,4–DA, and 2,5–DA in aqueous solution at 20, 19, and 16 gamma/ml., respectively.

RESULTS AND DISCUSSION

Figures 1 and 2 present the absorption curves obtained for the above chemicals in aqueous solutions when measured at known concentrations. The numerical value for the extinction coefficient or absorbency per unit concentration, k, is plotted on a logarithmic scale along the ordinate, and the wave length of light in angstrom units, along the abscissa. Beer's law was used in the form $k = \frac{1}{CX} \log_{10} \frac{I^o}{I^n}$ where I^o is the intensity of light energy transmitted by the solvent filled cell, and I^n is the intensity of light energy transmitted by the solution-filled cell. The thickness of the solution-filled cell in centimeters is represented by x, and the concentration of the

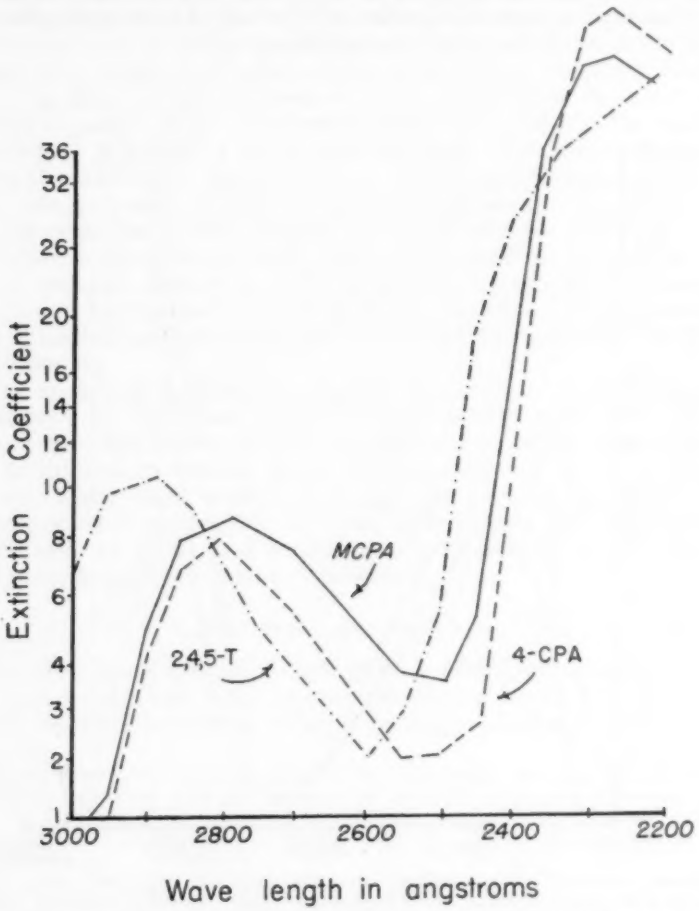

Figure 2. Absorption spectra of MCPA, 4-CPA, and 2,4,5-T in aqueous solution at 19 gamma/ml.

chemicals being measured in milligrams per milliliter is designated by c in the equation.

It is desirable to use light of wave lengths corresponding to the maximum absorbency or extinction of a system for a photometric determination. At this wave length, the greatest change in transmittance occurs for a given change in chemical concentration. From Figures 1 and 2, it can be noted that all chemicals used had two distinct extinction coefficient maxima. Beer's law was found applicable within 5% limits over a concentration range of 2 to 50 gamma per ml. for all chemicals when measured at wave lengths of light corresponding to the smaller, more distinctive, extinction peak. Figure 3

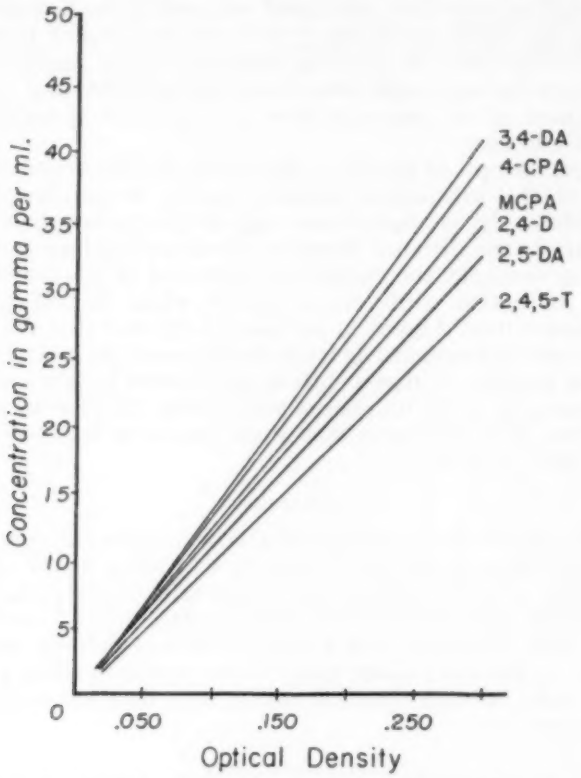

Figure 3. Working curves of several chlorinated phenoxyacetic acids determined at wave lengths of light corresponding to maximum extinction of from 2780 to 2880 angstroms at concentrations of from 2 to 50 gamma/ml.

illustrates this linear relationship between optical density and concentration for solutions of each chemical at known concentrations in series of dilutions.

The light wave bands, in angstrom units, corresponding to maxi-

Table 1. Comparison of wave bands of maximal absorption and extinction coefficients of several chlorinated phenoxyacetic acids.

Chemical	Molecular weight	Concentration gamma per ml.	Maximum angstroms	Extinction coefficients
2,4–D	221	20	2835	8.75
2,4–DNA	243	23	2835	8.70
2,4–DA	370	19	2835	8.76
2,5–DA	370	16	2800	9.18
3,4–DA	370	19	2835	7.52
MCPA	317	19	2780	8.45
4–CPA	335	19	2790	7.89
2,4,5–T	404	19	2880	10.17

mal absorption, and the calculated extinction coefficients for all chemicals, are listed in Table 1. It is of importance that 2,4–D, 2,4–DA and 2,4–DNa all have the same absorption maxima as well as similar extinction coefficients. This suggests that the nature of the side chain of the molecule does not significantly influence the absorptive efficiency.

However, the optical density of the molecule was influenced by the position of the substituted chlorine atoms in the benzene ring nucleus. Molecular configurations suggest that greater light absorption results as the distance between substituted chlorine atoms increases. For example, the extinction coefficient of 2,5–DA is greater than the extinction coefficient of 2,4–D, while that of 3,4–DA is smaller than either. Also of importance is the fact that the number of substituted chlorine atoms tends to influence the position of the absorption maxima in that a shift occurs toward longer wave bands with an increase in the number of substituted chlorine atoms in the ring nucleus. A maximum of 2880 angstroms occur for 2,4,5–T while that of 2,4–D is 2835.

SUMMARY

A rapid quantitative spectrophotometric analysis for various plant growth-regulating chemicals in aqueous solution is described. Chemicals studied were the sodium and amine salts of 2,4–D, 2,4–D acid, and the amine salts of MCPA, 2,5–DA, 3,4–DA, 2,4,5–T, and 4–CPA. Each of these chemicals was found to have a definite absorption maximum in the ultra-violet range of the spectrum. Beer's law was found to hold for each chemical over a concentration range of 2 to 50 gamma per ml.

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A Field Distributor for Granular Herbicide Trials[1]

L. L. DANIELSON and P. R. CHAMBERS[2]

THE granular herbicide distributor described here was devised to satisfy the need for equipment that would spread the clay type of granular carrier with a high degree of accuracy in small plot field trials. Performance data and construction details are presented for the benefit of others doing research on granular herbicides.

This distributor makes use of an auger as the basic metering device. A cross-sectional drawing of the auger and the slotted tube in which it turns is given in Figure 1. The alternate arrangement of

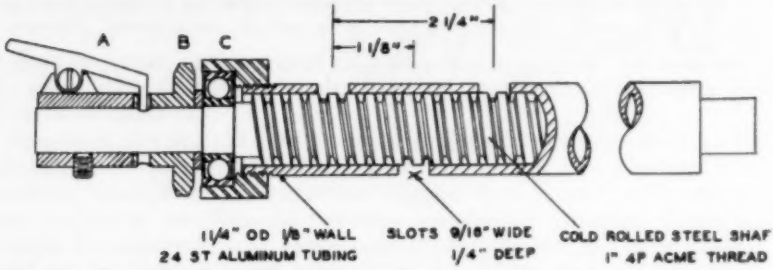

Figure 1. Cross-sectional diagram of a portion of the auger and slotted auger-tube. A—Simple clutch device to control operation of auger. B—Sprocket for drive chain. C—Ball bearing and supporting collar.

the slots at the top and bottom of the tube prevents the granules from running through at random by gravity. This positioning of the delivery and feeding slots makes this auger the equivalent of a series of small individual augers each of which delivers a uniform amount of granular material to be spread over equal soil areas with the aid of a splash pan.

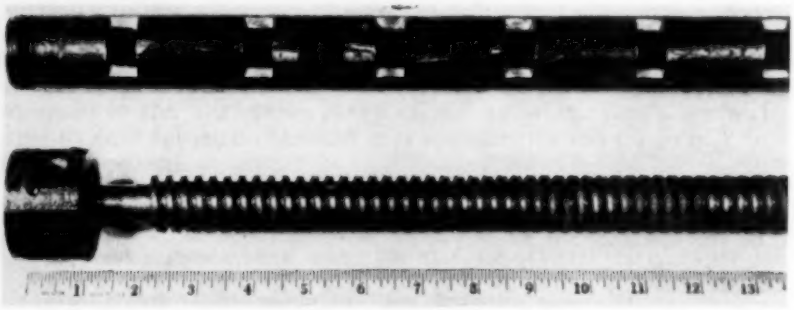

Figure 2. Section of auger and auger-tube.

[1]Contribution from the Plant Physiology Dept., Virginia Truck Exp. Sta., Norfolk. Paper No. 126, Journal Series. Approved for publication October 31, 1956.

[2]Plant Physiologist, and Scientific Aide in Plant Physiology, Virginia Truck Exp. Sta., Norfolk.

CONSTRUCTION DETAILS

Figure 2 is a photograph showing a portion of the assembled auger and slotted tube to demonstrate their relationship. As indicated in Figure 1, the auger is 1 inch cold-rolled steel shafting with a standard 1 inch 4P Acme thread. The slotted tube is 1¼ inch OD with ⅛ inch wall 24 ST aluminum tubing.

A completed operational distributor is shown in Figure 3. The auger in this unit is 6 feet long and there are 31 slots each on the top

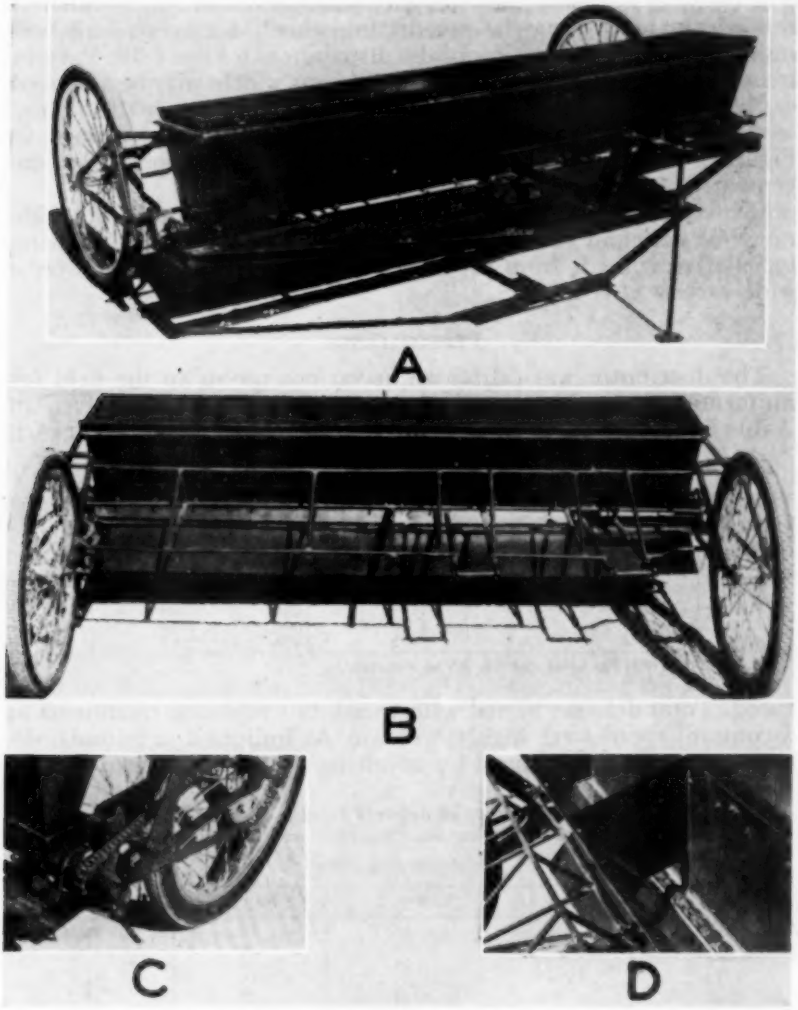

Figure 3. Views of operational distributor. A—Front view. B—Rear view showing wheel stalls for different row widths. C—Drive chain, sprocket, and clutch assembly. D—Interior of hopper.

and bottom of the tube. The auger is turned by means of sprockets and a chain. A 52 tooth sprocket is shown on the 24 inch bicycle drive wheel and a 10 tooth sprocket is shown on the auger. This ratio may be varied to change the rate of application. The hopper is constructed of 16 gauge sheet metal, 70 inches long, 12 inches high, 10 inches wide at the top, and 1¼ inches wide at the bottom. The lower ends of the hopper are cut to fit the outside of the auger-tube. Clamps are used to secure the hopper to the tube and the space between the hopper and the tube is sealed with caulking compound. The frame of this machine is designed to allow its use on a number of row widths by shifting the non-driving wheel to the various wheel stalls shown in the rear view of the distributor in Figure 3B. Various treatment patterns such as bands of different widths may be arranged easily by placing separators in the hopper and filling only the desired sections with the granular material. The simple clutch shown in Figure 1 makes it possible to stop and start auger operation conveniently.

It is visualized that this type of distributor can be built in a wide range of sizes and clearance heights to meet the needs of differing types of treatments from pre-emergence to lay-by application on a wide variety of crops.

PERFORMANCE

The distributor was calibrated at various speeds in the field for uniformity of total and individual slot delivery. Results given in Table 1 demonstrate that uniform total delivery was obtained at each

Table 1. Effect of speed on rate of delivery.

Speed mph	Wt. delivered in grams[3]				Av. wt. grams	Av. wt. lb/A
	Rep. 1	Rep. 2	Rep. 3	Rep. 4		
1.08	1172	1172	1176	1160	1170	46.7
2.08	1130	1117	1104	1084	1109	44.3
3.10	1037	1038	1038	1021	1034	41.3
4.02	1012	1012	1003	1000	1007	40.3

[3]From 400 ft. trial run using (30–40) RVM Attaclay.

speed. Total delivery varied with speed, but replicate treatments at a constant speed were highly accurate. As indicated previously, delivery rates can be changed by adjusting the sprocket ratio.

Table 2. Uniformity of delivery from individual slots.

Slot No.	Wt. delivered in grams[4]			Av. wt. grams
	Rep. 1	Rep. 2	Rep. 3	
1	24	25	24	24.3
4	24	25	24	24.3
8	23	24	24	23.7
12	24	25	25	24.7
16	23	23	22	22.7
20	23	23	23	23.0
24	24	25	24	24.3
28	26	26	25	25.7

[4]From 50 turns of the auger using (30–40) RVM Attaclay.

Comparison of delivery from individual slots given in Table 2 shows that delivery did not vary materially over the length of the distributor.

SUMMARY

Construction details and performance data on a granular herbicide distributor suitable for experimental field trials are presented. The metering device employed is an auger enclosed in a slotted tube. Delivery is uniform at each speed and directly related to distance traveled in the field. Overall or band applications can be made with this equipment and it is adjustable to rows of various widths.

The Influence of Soil-moisture Content on the Response of Cotton to Herbicides[1]

ROBERT P. UPCHURCH[2]

THE moisture content of soils is frequently reported to have an important effect upon the phytotoxicity of herbicides (1,3,4,6,10). Yet, specific experimental results establishing such relationships are, for the most part, lacking. Most moisture studies with herbicides have been designed to evaluate the effect of applied water on leaching and its indirect effect on volatilization and breakdown by exposure to sunlight. Some studies have shown the effect of moisture content on the rate of herbicide breakdown (2,7). Research on the fate of herbicides in soils has been summarized by Hill et al. (5) and Ogle and Warren (9). The experiments reported here were designed to establish the effect of soil-moisture content *per se* upon the response of cotton to 3–(3,4–dichlorophenyl)–1,1–dimethylurea (diuron), isopropyl–N–(3–chlorophenyl) carbamate (CIPC) and 4,6–dinitro ortho secondary butylphenol (DNBP) as the alkanolamine salts.

EXPERIMENTAL PROCEDURE

Portions of Cecil sandy loam soil weighing 1070 grams (oven-dry weight basis) were thoroughly mixed by hand with herbicide solutions in enamel mixing basins. These portions were transferred to one-quart cans of four-inch diameter having a uniform tare. Six, acid-delinted, ceresan-treated, Coker 100 Wilt cottonseed were planted one inch deep in each can. Immediately after planting all treatments were surface watered to the maximum level of "available" soil moisture. The maximum amount of available moisture for these studies was assumed to be that value which was half way between the moisture equivalent (8) and the free drainage value. The free drainage value was established by determining the equilibrium moisture content when one-quart cans of soil were saturated with water and allowed to drain for 140 hours through five one-eighth inch diameter holes in the bottom of each can. The lower limit of available moisture for this system (permanent wilting percentage) had been established in previous experiments by biological tests as being 11.2 percent. Four days after the first irrigation all treatments were again watered to the level of maximum available soil moisture and the moisture variables were put into effect from that date onward. Two weeks after planting the plant population for each can was reduced by thinning to the three healthiest specimens. At three and four weeks after planting the population was similarly reduced to two and one plants respectively.

[1]Contribution from the Field Crops Dept., North Carolina Agr. Exp. Sta., Raleigh, North Carolina. Published with the approval of the Director of Research as Paper No. 728 of the Journal Series.

[2]Assistant Professor of Field Crops, North Carolina State College. Currently on leave-of-absence with the United States Air Force, Eglin Air Force Base, Florida.

The four moisture levels used are shown in Table 1 along with the amount of depletion allowed for each treatment. Each can was weighed as often as necessary to determine the time to add water so that the limits set in Table 1 might be maintained. All water additions were made to the soil surface. Since there were no holes in the bottom of the cans, leaching of herbicide from the cans was eliminated as a factor in these experiments.

Table 1. Soil moisture levels used in Experiments I and II.

Moisture level	Degree of available water depletion allowed	Weight of cans—grams		Soil moisture percentage just prior to irrigation
		Just prior to irrigation	Just after irrigation	
A	none	1420 ± 5	1435[1]	21.9
B	⅓	1385 ± 10	1425	19.0
C	⅔	1345 ± 10	1425	15.1
D	all	1305 ± 10	1425	11.2

[1]The A treatments were irrigated to 1435 rather than 1425 grams because an attempt was being made to hold the moisture content as near 1425 (no depletion) as possible.

Essentially the same procedure was followed in two experiments. In Experiment I, diuron alone was used at rates of 0, 2, 3, 4 and 5 ppm (oven-dry soil basis). In Experiment II diuron was used at 0, 2, 3 and 5 ppm while CIPC and DNBP were each used at rates of 0, 20, 30 and 50 ppm. Experiment I was terminated six weeks after planting. Experiment II was terminated five weeks after planting, since the rate of water used by the plants made the maintenance of the moisture variables difficult. At the conclusion of the experiments green and dry weights of plant tops were recorded as well as heights of the green plants for Experiment II. All treatments were watered within 12 hours of harvest. A complete randomized block design with six replications was used for each experiment.

These experiments were conducted in the greenhouse from November, 1954 to February, 1955. Growing conditions were better in the latter part of this period than in the first part. Air temperatures were maintained above 75°F. and below 95°F. for the period of these experiments. For the greater part of this period, temperatures ranged between 78° and 88°F. The plants of Experiment I were subjected to a severe attack by damping-off organisms. In Experiment II, damping-off was combated by directing approximately one cc of a two gram per liter solution of 50 percent captan at the base of the hypocotyl of each plant on the day after emergence.

RESULTS

The results of Experiment I are shown in Table 2. For each of the herbicide treatments and the check treatment, the regression of production "y"[3] (green and dry matter) on moisture level "x" has been calculated and the resulting slope values "b" or regression coefficients

[3]Terminology of Snedecor, George W. Statistical Methods. 4th Ed. Iowa State College Press, Ames, Iowa. 1946.

with their standard errors are presented in Table 2. Except for occasional missing plots, 24 values were used to calculate each b value. The regression equation for each of these treatments has been calculated using the formula, "predicted" $Y = \bar{y} + b(X - \bar{x})$. For this calculation the A, B, C and D moisture levels were assigned values of 1, 2, 3 and 4 respectively with a resulting $\bar{x}$ of 2.50.

Regression equations for Experiment I have been plotted in Figure 1 to give a graphic illustration of the general responses obtained.

Table 2. The response of cotton to diuron under various soil moisture conditions. Expt. I

Diuron application ppm	Soil moisture level[1] A	B	C	D	Mean ($\bar{y}$)	Regression coefficient (b)	Standard error of reg. coef. $\times 10^{-2}$ (S_b)	Response index $\left(\frac{b}{\bar{y}} \times 100\right)$
					Dry shoot yield—gms/plant			
0	0.93	0.78	0.60	0.56	0.72	−0.130	0.73	18.1
2	0.61	0.44	0.48	0.51	0.51	−0.035	1.30	6.9
3	0.32	0.31	0.32	0.32	0.32	−0.003	0.14	1.0
4	0.21	0.28	0.23	0.24	0.24	−0.006	3.98	2.6
5	0.20	0.18	0.17	0.16	0.18	−0.013	0.02	7.1
					Green shoot yield—gms/plant			
0	7.94	6.85	4.78	4.16	5.75	−1.327	6.12	23.1
2	5.45	3.85	4.12	4.23	4.41	−0.423	11.36	9.6
3	2.72	2.52	2.60	2.32	2.54	−0.121	1.53	4.8
4	1.43	1.95	1.63	1.33	1.56	−0.072	6.51	4.6
5	1.20	1.12	0.90	0.80	1.01	−0.135	1.07	13.4

[1]A, B, C and D treatments were irrigated when respectively 1/12, 1/3, 2/3 and all of the available moisture has been extracted.

Where no herbicide was applied, a definite response to the soil moisture variable was obtained. Seventy-five percent more dry matter was produced by cotton where the soil-moisture content was maintained near the maximum available amount (level A) as compared to where all of the available moisture (level D) was allowed to be extracted before irrigating to the maximum amount of available soil moisture. Quite a different degree of response was obtained where diuron was used. This chemical caused a decrease in production which was proportional to the amount used. Inspection of the graphic presentation in Figure 1 indicates that cotton grown with diuron was much less responsive to moisture treatments than cotton grown without this herbicide. However, a true evaluation of this difference in responsiveness to moisture variables is difficult to make by inspection of Figure 1. This is due to the fact that the slope of the regression lines would be expected to depend on the value of $\bar{y}$ (average dry or green weight), if one assumes that there is a constant relative response of yield to moisture variable. A nonbiased comparison is made possible by computing the ratio of the b value of a given regression line to its $\bar{y}$ and multiplying by 100. This value or response index is the percentage change in Y for each unit of change in X. It should be a constant regardless of the value of $\bar{y}$, provided that there is a constant relative response of the Y variable to the X variable. If a response index deviates significantly from the

response index of the no herbicide treatments, a change in the magnitude of response to moisture variables is indicated. Response indices lower than that of the check indicate that the herbicide caused the yield response to be less affected by moisture variables than was the case without herbicide and the reverse is indicated by response indices being greater than that for the check.

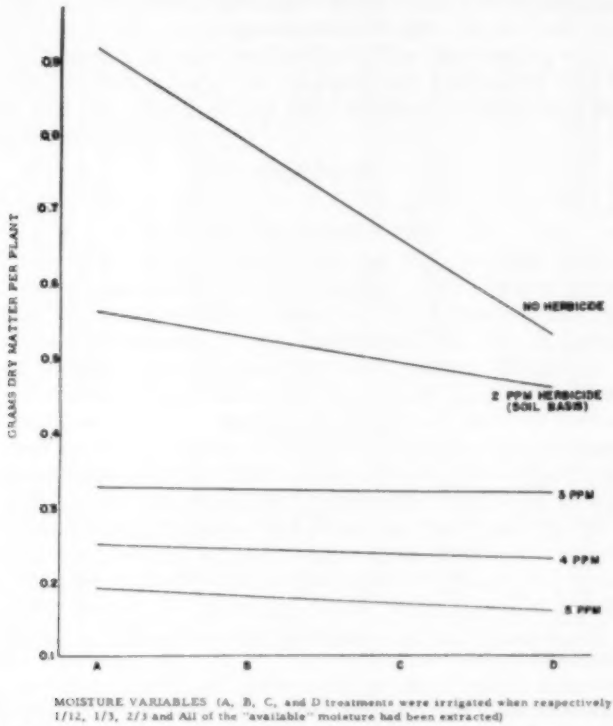

Figure 1. The response of cotton to diuron as measured by dry shoot yields under various soil moisture conditions as shown by plotted regression equations. Expt. I.

The response indices for Experiment I show that the incorporation of diuron into the soil caused cotton to be less responsive to soil-moisture variables than was the case where no herbicide was used (Table 2). This decrease in responsiveness was greatest at the intermediate rates of 3 and 4 ppm of urea herbicide and was least at the extreme rates of 2 and 5 ppm.

Essentially the same experimental procedure was used in a second experiment to repeat the diuron treatments and to compare the response obtained with those for DNBP and CIPC. The results from the diuron variables for Experiment II are in essential agreement with those of Experiment I with minor deviations (Table 3). In Experiment II diuron was more effective in reducing growth than

Table 3. The response of cotton to diuron, CIPC and DNBP herbicides under various soil moisture conditions. Expt. II.

Herbicide and appl. ppm	Soil moisture level[1] A	B	C	D	Mean ($\bar{y}$)	Regression coefficient (b)	Standard error of reg. coef. $\times 10^{-2}$ (S_b)	Response index $\left(\frac{b}{\bar{y}} \times 100\right)$
Dry shoot yield—gms/plant								
None.....	1.63	1.55	1.29	0.98	1.36	−0.226	1.17	16.6
None.....	1.69	1.33	1.37	1.10	1.37	−0.172	1.71	12.6
Diuron 2	0.65	0.73	0.62	0.63	0.65	−0.018	0.77	2.7
Diuron 3	0.36	0.31	0.37	0.39	0.36	−0.015	0.50	4.1
Diuron 5	0.13	0.16	0.14	0.11	0.13	−0.008	0.37	5.8
CIPC 20	0.40	0.24	0.31	0.23	0.29	−0.045	1.04	15.5
CIPC 30	0.21	0.17	0.12	0.07	0.14	−0.047	0.07	33.7
CIPC 50	0.12	0.11	0.08	0.05	0.09	−0.024	0.12	26.4
DNPB 20	0.38	0.43	0.37	0.28	0.36	−0.037	0.63	10.2
DNPB 30	0.08	0.07	0.05	0.07	0.07	−0.008	0.16	11.3
Green shoot yield—gms/plant								
None.....	12.30	11.45	9.24	6.70	9.92	−1.933	8.80	19.5
None.....	12.68	10.35	10.12	7.62	10.19	−1.532	9.93	15.1
Diuron 2	5.66	6.32	5.08	4.85	5.48	−0.387	7.82	7.1
Diuron 3	2.95	2.52	2.92	3.27	2.92	−0.137	4.29	4.7
Diuron 5	—	1.37	0.40	0.70	0.82	−0.333	10.65	40.6
CIPC 20	2.18	1.70	1.64	1.25	1.69	−0.290	1.90	17.2
CIPC 30	1.02	0.87	0.56	0.52	0.74	−0.181	1.22	24.5
CIPC 50	0.42	0.58	0.50	0.10	0.40	−0.045	2.86	11.3
DNPB 20	2.27	2.33	2.07	1.63	2.08	−0.217	2.43	10.4
DNBP 30	0.42	0.38	0.35	0.37	0.38	−0.020	0.34	5.2
Plant height—cm/plant								
None.....	24.1	23.5	21.5	18.9	22.0	−1.806	10.14	8.2
None.....	25.4	22.1	21.7	19.7	22.2	−1.737	11.52	7.8
Diuron 2	18.1	18.7	16.9	16.9	17.6	−0.574	9.62	3.3
Diuron 3	17.1	15.1	16.3	14.4	15.7	−0.716	13.36	4.6
Diuron 5	10.4	10.7	11.1	11.1	10.8	−0.245	2.37	2.3
CIPC 20	10.1	8.0	9.3	7.5	8.7	−0.650	15.55	7.5
CIPC 30	7.6	7.3	6.4	5.1	6.6	−0.834	5.16	12.7
CIPC 50	6.5	5.2	4.8	4.1	5.1	−0.753	4.79	14.7
DNBP 20	12.4	12.6	10.6	9.7	11.3	−1.003	8.24	8.9
DNBP 30	3.9	4.3	3.9	3.8	4.0	−0.057	3.91	1.4

[1]A, B, C and D treatments were irrigated when respectively 1/12, 1/3, 2/3 and all of the available moisture had been extracted.

in Experiment I. The response index for green matter production at 5 ppm of diuron may be considered anomalous since this rate caused highly variable amounts of desiccated leaf tissue on the cotton plants.

Based on experience with pre-emergence type applications under field conditions, the CIPC and DNBP rates for this experiment were selected as ten times the rates used for diuron (10). These herbicides were more active under the conditions of this experiment than had been anticipated and the highest rate of DNBP gave no useful data. In general, the height, green weight and dry weight data for the B, C and D levels receiving DNBP and CIPC herbicides show that the same degree of reduction was obtained, compared to the corresponding A level, as would have been predicted from the B, C and D levels which received no herbicide. This is best illustrated by the fact that the response indices presented in Table 2 do not vary greatly from that of the check treatment with the exception of the 30 ppm rate of DNBP (height and green matter production). This exception is

a valid one but it applies only to the condition where plant growth has been affected in an extremely adverse manner—i.e. the green matter yield for 30 ppm of DNBP is only four percent as great as the no herbicide treatment. Thus in this experiment, the response of cotton to soil-moisture variables was not greatly influenced by the presence of CIPC or DNBP. However, only highly toxic levels of DNBP and CIPC herbicides were used. The lowest rate of DNBP and CIPC used (20 ppm) produced 74 and 79 percent reductions respectively in dry matter production. The interaction which might be obtained between responses to these two herbicides and moisture variables at rates which would give moderate reductions in growth remains to be evaluated.

DISCUSSION

The results of the experiments reported show that soil-moisture content, as varied in these experiments, has only slight actual influence but large relative influence on the response of cotton to diuron. The explanation for such a relationship is not immediately clear from the data available. However, the following description of the possible components of the regression line for the response of cotton to moisture in the presence and absence of diuron may be helpful. For this description the regression lines which were calculated from actual data for 3 ppm of diuron and no herbicide are shown in Figure 2 as solid lines. The response to moisture which should have been obtained from plants grown with 3 ppm of diuron if the relative rate of response to moisture variables observed for the check had been obtained (i.e. if diuron had affected the level of production but not the rate of response to moisture) is shown as a broken line. This line (predicted moisture component) is obtained by assuming that b_c (b value for check) $\div$ $\bar{y}_c$ ($\bar{y}$ value for check) = b_{mc} (b value for moisture component) $\div$ $\bar{y}_{to}$ ($\bar{y}$ value for treated observed) where b_c, $\bar{y}_c$ and $\bar{y}_{to}$ are experimentally obtained values and b_{mc} is solved for as an unknown. If this broken line (moisture component) was actually a component of the observed regression line, the actual response of the plant to the herbicide under varying moisture, as a component of the observed regression line, is obtained by assuming $\bar{y}_{hc}$ (herbicide component) to be the same as $\bar{y}_{to}$ and by calculating the b_{hc} as follows:

$$b_{hc} = b_{to} + (b_{to} - b_{mc})$$

The response for this derived herbicide component is shown as a dotted line in Figure 2.

Under these assumptions diuron is shown not only to be relatively more toxic under high soil moisture conditions as compared to low soil moisture conditions, but to be more toxic from an absolute standpoint. When one looks at the observed values in Figure 1 the lowered yield resulting from the increased toxicity of the herbicide under high moisture levels is masked by the direct reverse response of the plant to the moisture variable.

The assumption that the response of cotton to the moisture variable is relatively the same in the presence of diuron as in its

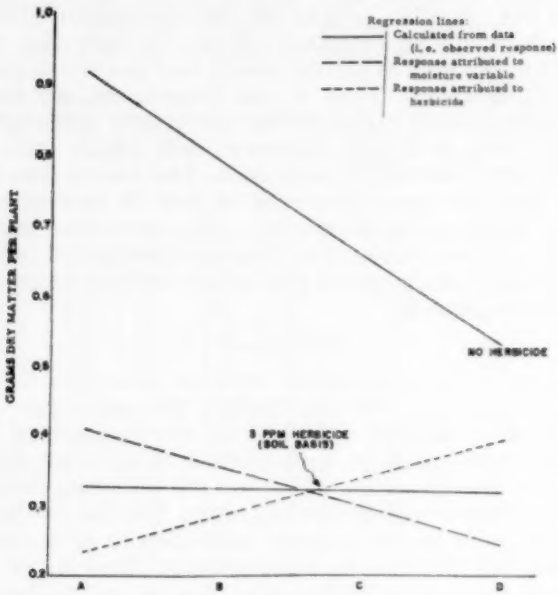

Figure 2. An illustration of the possible components of a regression line showing the response of cotton, as measured by dry shoot yield, to diuron under various soil moisture conditions. Expt. I.

absence is basic to the above discussion. It is quite possible that this assumption is not justified and that the description of the possible components provided is not valid. For example, diuron might cause some growth factor to become limiting to such an extent that the plant does not give a response when some other factor, such as soil moisture, is provided in more or less favorable amounts. Although this possibility exists there is no concrete evidence at this time to indicate that it applies to the situation at hand.

The response of cotton to the combined variables of soil moisture and diuron seems at first glance to be at variance with the common belief that soil moisture is critical in obtaining good weed control from pre-emergence applications of the substituted urea herbicides under field conditions. If weeds respond to these variables as did cotton, one might say that essentially the same weed growth would be obtained in the presence of diuron over a wide range of soil moisture conditions and that, as a corollary, soil moisture is not critical for weed control. On the other hand, the weed growth under different moisture conditions would have varied considerably had the herbicide not been present. Obviously there are two ways of regarding the response both of which are perfectly sound provided the proper phraseology is used.

Two items should be considered in examining the fact that these experiments do not show less growth under high soil moisture than under low soil moisture where diuron has been used. One factor is that the critical experimental data for establishing the supposed relationship under field conditions is scarce or lacking at this time. A second factor for consideration is that the manner of application of herbicides and the natural variation of soil moisture under field conditions are not exactly the same as for these experiments. Furthermore, the criterium of weed control as a measure of herbicidal activity may give different results than the criteria of height, green matter and dry matter production of cotton. This discrepancy is of importance because these experiments were designed to be a first step in evaluating the influence of soil moisture variables under field conditions on the response of plants to herbicides. Further experiments are needed.

DNBP and CIPC are generally reported to be more effective for pre-emergence weed control under conditions of moderate rainfall. The fact that soil moisture content was not found to influence the relative response of cotton to these herbicides may be taken to indicate that the function of the moderate rainfall requirement is to maintain effectiveness by preventing loss through leaching or volatility, rather than having a direct influence on the activity of the herbicides.

SUMMARY

The response of cotton to diuron, DNBP and CIPC herbicides under varying soil moisture regimes was investigated. Individual plants were grown in one quart cans of soil in which the soil moisture was allowed to be depleted to 1/12, 1/3, 2/3 or all of the available supply before being irrigated to the maximum available amount. The principal results were as follows:

1. Where no herbicide was mixed with the soil the high moisture level produced over 50% more dry matter than the drier levels.

2. Soil mixed with diuron produced plants having nearly equal amounts of green matter, dry matter and plant heights under all soil moisture levels. Thus soil moisture had no absolute effect but a large relative effect on the observed phytotoxic properties of diuron.

3. Assuming that cotton plants respond relatively the same to moisture variables with and without diuron, it was shown that diuron is more toxic under moist soil conditions than under dry soil conditions.

4. Plants grown in soil treated with CIPC or DNBP were not influenced by soil moisture variables to an extent greater than that anticipated from the performance of plants grown under moisture variables in the absence of herbicides.

Possible explanations of these results were discussed. Their meanings were presented in light of previous observations made under field conditions.

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Investigations of the Use of 2,4,5–T Esters as a Basal Spray in the Control of Bear Oak[1]

D. P. Worley, W. C. Bramble, and W. R. Byrnes[2]

Introduction

Bear oak (*Quercus ilicifolia* Wang.) is widely recognized as difficult to eradicate. Burning, cutting, and routing, while killing the original stems to the ground, have caused dormant buds on the root collar to become active and produce fast growing sprouts which soon replace the original plant. In fact, single-stemmed plants so treated can produce as many as 40 or more new stems. Moreover, this species has been difficult to control chemically owing to resurging growth from the root collar and lower stem after a kill of original stems. Bear oak is widely distributed as an understory tree in the eastern United States extending from Maine to North Carolina and from the Atlantic Coast to Ohio and Kentucky. Often it develops into dense thickets on burned-over forest land or abandoned fields so that it monopolizes the site, crowding out other more desirable species and making planting of other trees an expensive operation. One hundred and fifty to two hundred thousand acres of such "scrub oak barrens" occur in Pennsylvania[3].

In the last 10 years, a number of chemical sprays have been used in an effort to control various species of woody brush. Of these, the 2,4,5–T esters carried in an oil base and sprayed on the lower 12 to 18 inches of the stem so as to allow ample rundown have proved promising for controlling bear oak. Basal treatment of bear oak with these chemical sprays was begun by The Pennsylvania State University in 1950. These early tests produced such highly erratic results that in 1952 a series of more detailed tests were initiated to investigate some of the factors which it was felt might contribute to this variability. The first tests were designed to find the basic factors operative, later tests to develop techniques to produce results consistent with the preliminary findings.

Methods

The experimental design used in these tests required field testing of groups of 10 to 20 plants by subjecting them to different treatments and comparing the results statistically. In tests using balanced groups these results were tested by subjecting the data to an analysis of variance. Those groupings which were not balanced were tested by the chi-square test or by computing regression lines where this was appropriate and determining the significance of these regressions. The graphs shown were constructed by expressing the number of

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[2]Asst. Prof. of Forestry, Prof. of Forestry, and Inst. of Forestry, resp.

[3]Anon. Scrub oak in Pennsylvania. Penna. Dept. of Forests and Waters. 1951.

plants affected in each group as a percentage of the total number of plants in the group.

Two criteria were defined so as to evaluate the effectiveness of the treatments applied.

Topkill is of immediate practical interest to anyone engaged in chemical brush control for it indicates the death of the above ground portions of the plants. In these tests, topkill is defined as complete defoliation and death of the entire stem including bark and cambial tissue. The former was determined by observation, the latter by lightly scraping or shaving the bark where death of these tissues was not clearly evident.

Topkill not resprouting evaluates more permanent control or eradication. Plants which were topkilled were examined with respect to their subsequent sprouting ability. Each plant was carefully inspected for sprouts after each of the three growing seasons since treatment. If a topkilled plant had no living sprouts it fell into this classification.

Field treatments in all tests were completed before the 1953 growing season so that the records are for at least three years following treatment. Data were taken and analyzed in September or October each year after treatment. It is important to note that the results of

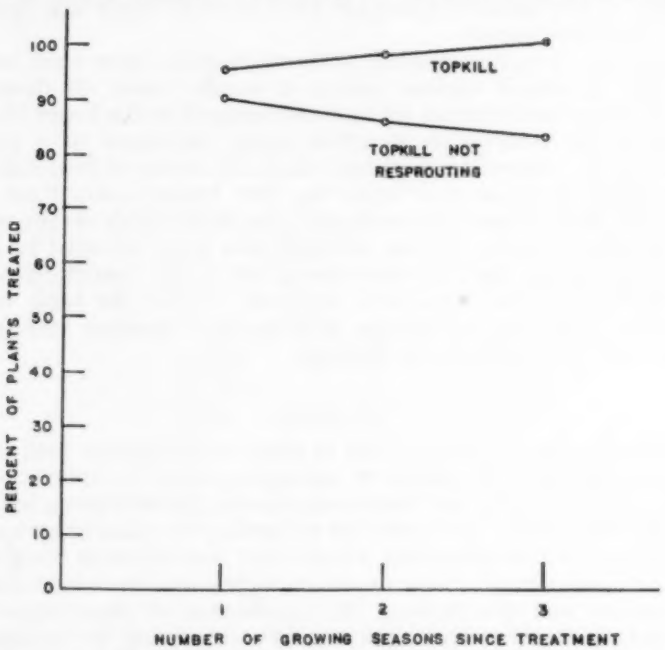

Figure 1. Composite trends in percent bear oak plants *topkilled* and those *topkilled not resprouting* for 3 growing seasons after basal spraying with 2,4,5–T in oil irrespective of dates, volumes or concentrations of application.

the analyses of these tests changed from year to year, due generally to progressive topkill and a gradual increase in resprouting as shown in Figure 1.

This being the situation, some factors involved in chemical application which appeared highly significant after the first growing season, had by the third growing season after treatment lost some or all of their significance. Considering these facts then it is important that brush control experiments with hard to kill species, conducted on the basis of field trials, be permitted to pass through at least three growing seasons before any final conclusions be drawn from them.

TECHNIQUES AND RESULTS

Effect of Placement and Season

The first series of basal tests were conducted on March 15, 1952 and August 1, 1952 in order to determine the importance of date of application and to determine whether the chemical was more effective when applied to one part of the lower stem-root collar region of the plant or another. 2,4,5–T[4] was used in these tests at a concentration of 4 percent by volume in kerosene (12 pounds acid equivalent per 100 gallons of solution). Five different applications were made on each date with 10 plants in each group. Some of these were applied with a brush so as to localize the treatment, others were treated by conventional spraying techniques, as follows:

1. The spray material was applied with a brush so as to cover both the lower stem and the root collar which had been exposed by digging away the litter and surface soil.
2. The spray material was applied with a brush so as to cover only the root collar.
3. The spray material was applied with a knapsack sprayer to completely encircle the lower 12 inches of the stem and, as in usual basal spray procedure, an excess was allowed to run down the stem toward the root collar.
4. The spray material was applied with a brush to completely cover the lower 12 inches of the stem without allowing any of the chemical to run down to the root collar.
5. The spray material was applied with a knapsack sprayer so as to cover the ground surface in a two-foot circle around the plant, being careful not to spray the plant itself.

It soon became apparent that the ground spray as it was applied produced no visable effect so this group was discarded from further consideration. Data taken after the 1953 and 1955 growing seasons are presented graphically in Figure 2.

Considering all treatments it appears that winter is the superior season for treatment. More intensive investigations described later in this paper bear out the conclusion that significant differences occur with different seasons of application. Of the treatments tried, with-

[4]Butoxyethanol ester of 2,4,5–trichlorophenoxyacetic acid, 3 pounds acid equivalent per gallon.

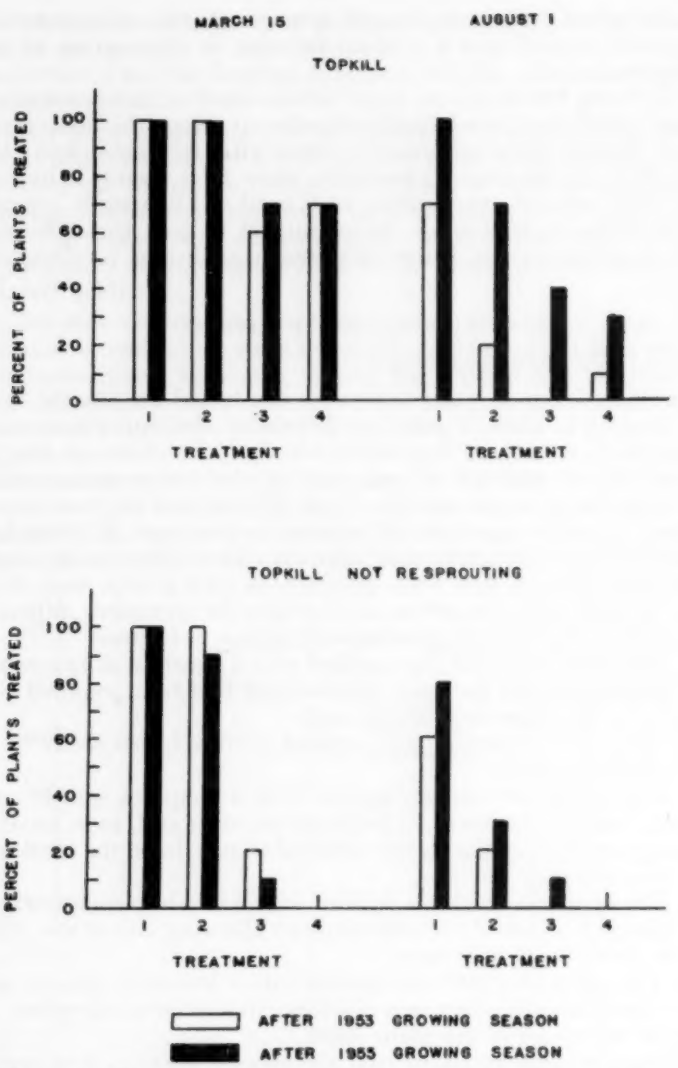

Figure 2. The effect of date and point of application of spray material on percent of bear oak plants *topkilled* and *topkilled not resprouting*, one and three growing seasons after basal treatment with 2,4,5-T in oil. Treatment 1—Brushed on root collar and base of stem 2—Brushed on root collar, 3—Basal spray, 4—Brushed on base of stem.

out regard to season, those which enabled the spray solution to reach the root collar were most successful in suppressing resprouting in top killed plants. This superiority was shown to be statistically significant at the 5 percent level by an analysis of variance.

Season and Concentration

The first year results of the season and placement tests led to the establishment of further tests to investigate the seasonal aspects more thoroughly. A second objective was to determine the minimum concentration of 2,4,5–T esters in oil which would be effective. Other test have shown that a drop in effectiveness has occurred at concentrations below 12 pounds acid equivalent per 100 gallons of solution. Duplicated groups of 10 bear oak plants were treated by spraying the bases of the stems to the point of runoff. The applications were made using four different concentrations at four different dates. One concentration which it was felt would definitely produce good results was applied at 10 different dates as shown in Table 1.

Table 1. Dates of application and concentrations of 2,4,5–T in oil used as basal treatments in season and concentration studies.

Date of application	Concentration—percent by volume	Pounds 2,4,5–T acid equivalent per 100 gallons
December 18	0.9, 1.7, 2.6, 3.4	3.6, 6.8, 10.4, 13.6
January 19	2.6	10.4
February 25	2.6	10.4
March 30	0.9, 1.7, 2.6, 3.4	3.6, 6.8, 10.4, 13.6
May 6	2.6	10.4
June 10	0.9, 1.7, 2.6, 3.4	3.6, 6.8, 10.4, 13.6
July 15	2.6	10.4
August 21	2.6	10.4
September 30	0.9, 1.7, 2.6, 3.4	3.6, 6.8, 10.4, 13.6
November 12	2.6	10.4

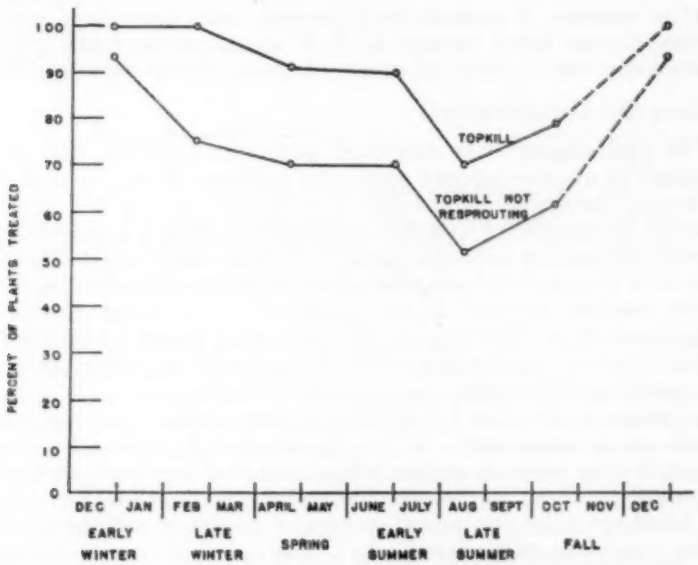

Figure 3. The effect of season of application on percent of bear oak plants *topkilled* and *topkilled not resprouting*, three growing seasons after treatment with basal applications of 2,4,5–T esters in oil (10.5 pounds acid equivalent per 100 gallons).

Variations due to date of application proved significant at the 5 percent level for each of the three annual sets of data for the 2.6 percent by volume applications. The magnitude of this variation is shown for the third growing season after spraying in Figure 3. Local phenological seasons are shown instead of actual dates so that the results can be better appreciated by readers in other parts of the range of bear oak.

Variation in *topkill* due to the different concentrations used was significant at the end of the first year but not thereafter. Differences in *topkill not resprouting* due to variation in concentration were not significant at any time. Close inspection of the data however revealed that the different concentrations applied in the dormant season (December and March) affected the results in a seemingly logical manner. Since this has proved to be a good season for treatment a new analysis was made using only dormant season data. It was found in this restricted analysis that variation due to the concentration used was indicative at the 20 percent level. Even though this level of significance cannot be considered conclusive evidence of the importance of concentration it is certainly indicative particularly in view of the results shown graphically in Figure 4.

Figure 4 shows that the variation due to different concentrations indicated in the analysis is due entirely to the poorer results obtained from the 0.9 percent by volume concentration. It appears that there is little choice between the other three concentrations and it is reasonable to conclude that concentrations much below 1.5 or 2 percent by volume (6 pounds to 8 pounds acid equivalent per 100 gallons) do not bring enough 2,4,5–T in contact with the plant to produce successful *topkill* let alone adequate *topkill not resprouting*.

Volume and Concentration

The preliminary tests described earlier had shown that it was necessary to wet the exposed root collar portions of the plant in order to obtain successful *topkill not resprouting*. It was felt that this could be accomplished in a more practical manner by increasing the volume of treating solution applied at lower than usual concentrations over that normally applied when using as a criterion "spray till ample rundown occurs." It was reasoned that a volume limit could be determined at which point the root collar would be flooded and topkill without resprouting could be approached consistently with low concentration sprays.

In order to test this hypothesis an experiment was designed in which two concentrations of 2,4,5–T in oil (1.5 percent by volume, 6 pounds acid equivalent per 100 gallons and 3 percent by volume, 12 pounds acid equivalent per 100 gallons) were applied as a dormant basal spray to duplicated groups of plants at different volume levels. Since the experiment was conceived in terms of increasing normally applied volumes, it was first determined that to obtain a moderate rundown using the hand garden tank sprayer available required spraying the base of each stem for five seconds. A plant with four stems would have each stem sprayed for five seconds or 20

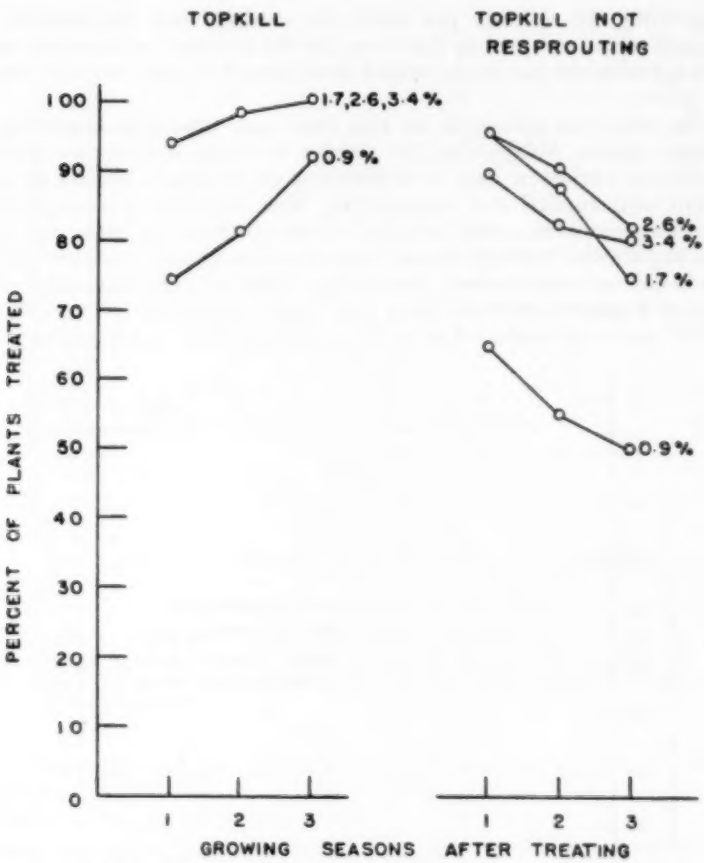

Figure 4. The effect of different concentrations of 2,4,5–T in oil, expressed as percent by volume and applied as a basal treatment, on percent *topkill* and *topkill not resprouting* of bear oak for the first 3 growing seasons following treatment.

seconds for the entire plant. The experiment provided for spraying four groups of plants (two with each concentration) for five seconds per stem, four groups for 10 seconds per stem and four groups of plants for 15 seconds per stem. In order to insure a consistent and adequate flow of chemical throughout the experiment it was necessary to bring the tank to full pressure before spraying each plant. As part of the systematic experimental procedure the actual volume used was measured after spraying each group of plants. This volume was divided by the number of five second applications made for that group in order to determine the average volume per five second application for that group and the consistency of this variable between groups. This was calculated and found to be 0.95 ± 0.14 ounces. It was felt that this variation was not a serious deterrent to

computing the volume per plant by multiplying the number of original stems composing the plant by the average volume per stem. Average volumes per plant varied then from 0.95 ounces to 36 ounces per plant.

The data was arranged on this basis and classified according to volume classes. Subjecting the results to a chi square test showed significant variation due to differences in volume applied in both *topkill* and *topkill not resprouting* after the first growing season since treatment but only for *topkill not resprouting* after the third growing season. No significant variation was found in either *topkill* or *topkill not resprouting* due to the different concentrations used. Figures 5 and 6 show the data and linear relations for *topkill* and *topkill not resprouting* due to successive volume applications.

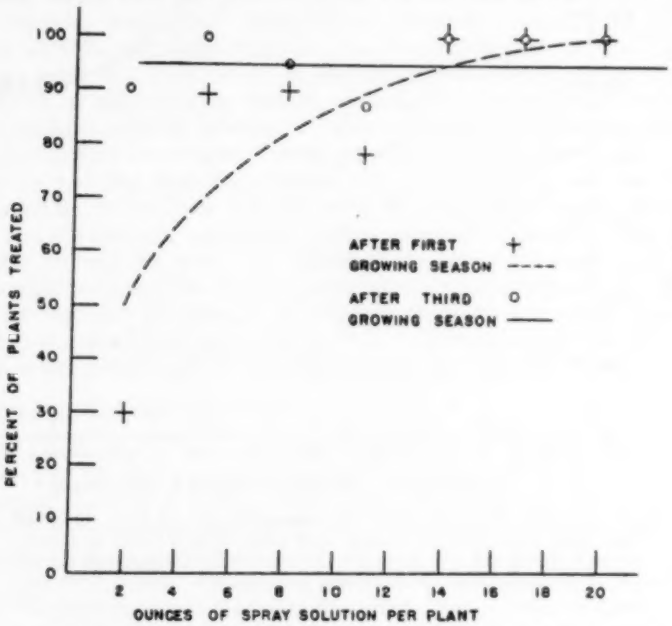

Figure 5. Topkilled plants expressed as a percent of plants treated with different volumes of dormant basal spray of 2,4,5–T esters in oil following the first and third growing seasons after spraying.

Data for both the first and third growing season are shown because they reflect the consistent increase in *topkill* and *topkill not resprouting* found in these experiments using basally applied 2,4,5–T esters in oil on bear oak.

It is important to note from Figure 5 that perfect *topkill* results were obtained quickly from the high volume applications and that the increase in *topkill* is greater for the low volumes than the intermediate volumes until after the third growing season when there is little to choose between them. Since the variation in *topkill* due to

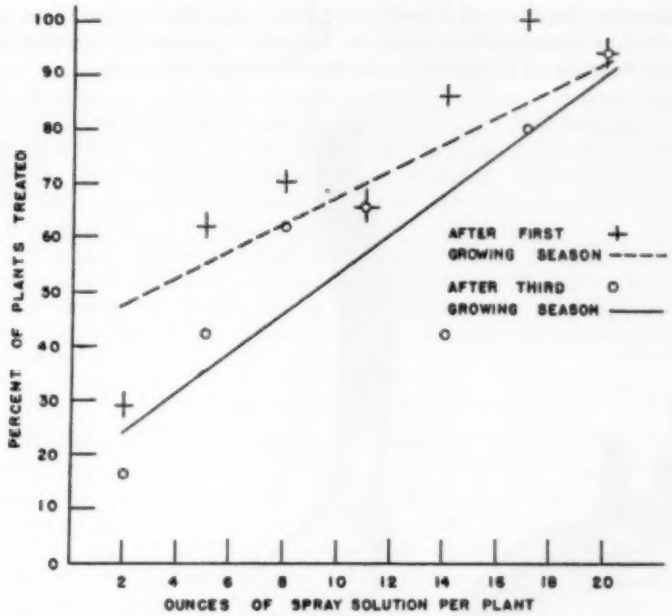

Figure 6. Topkill not resprouting plants expressed as a percent of plants treated with different volumes of dormant basal spray of 2,4,5–T esters in oil following the first and third growing seasons after treatment.

the volume applied was not significant in the third growing season, an average *topkill* of 95 percent suffices for all volumes with a standard deviation of 5 percent.

Since the third growing season data for *topkill not resprouting* illustrated in Figure 6 was shown significant by the chi square test, a regression was computed in the form of $Y = a + bX$ in which

Y = the percent of plants *topkilled not resprouting*

X = the ounces of treating solution applied

The computed coefficients a and b of the regression produced the following formula:

$$Y_c = 16.14 + 3.89\,X$$

This formula has a standard deviation of 18 percent, nearly four times greater than that for *topkill*. This high variation may be accounted for by the irregularity of the root collars found in bear oak. Occasionally these lie in a vertical position immediately below the plant. This forms an ideal avenue for the treating solution to reach and flood the root collar. More often, however, the stems break the soil and litter surface several inches to a foot or more away from the root collar which makes for inefficient transmission of the treating solution to the root collar zone. Also many of the root collars are not vertical but lie in a horizontal position, a situation which further

complicates the flow of basally applied solution to the root collar. This fact is clearly illustrated in Figure 7 which shows the longitudinal sections of 2 plants receiving different volumes.

Figure 7. Sections of two bear oak plants made two growing seasons after a dormant basal treatment with 2,4,5–T esters in oil. The tree on the left received 20 ounces of 1.5 percent by volume solution while the tree on the right received only 2 ounces of 3 percent solution. Discolored portions above the dashed line are dead tissue while the lighter portions below were still alive at the time of sectioning.

Close inspection of Figure 7, taken two years after spraying, shows first, that the number of stems may have no relation to the size of the root collar or extent of the root system, and secondly, that bear oak root collars are highly variable in configuration. It is also important

to note that the dead portions of the root collar varied directly with the volume of treating solution applied. It seems that a flooding action was obtained through use of the higher volume but since the root systems below this point were still alive it is doubtful that the translocation to the roots had taken place. Furthermore, callus tissue had developed at the top of the live root portion of the tree receiving the least volume which presumably, if not attacked by a secondary agent, would be capable of creating a new root collar and new shoots some years later.

To summarize the volume tests, then, it can be said that high volumes produced *topkill* more quickly than the lower volumes but that the results are about the same after three years. High volumes on the other hand were necessary to produce effective *topkill not resprouting*.

SUMMARY AND CONCLUSIONS

A series of field tests using 2,4,5–T esters in oil applied as a basal spray to bear oak *(Quercus ilicifolia* Wang.) were conducted by The Pennsylvania State University in 1952 and 1953. All of these tests have been carefully followed for three growing seasons after treatment. Two criteria were used to evaluate the data: (1) *Topkill* which required that no living tissue be found above ground on the original stems, and (2) *Topkill not resprouting* in which top killed plants showed no above-ground evidence of sprout activity. Three separate series of field tests were carried out to determine (1) the effect of different placements of the spray material on the plant, (2) the effect of the concentration of 2,4,5–T esters in the spray solution, (3) the effect of applying the spray in different seasons, and (4) the effect of increasing the volume of spray solution beyond that normally applied in current techniques.

In general, it became evident from all the tests that results change from year to year due to progressive *topkill* and increased resprouting. The net result of these trends was an improvement in *topkill* each year and poorer results in *topkill not resprouting* each year. Because of these trends it is recommended that no final conclusions from field trial tests with difficult to kill species be drawn for at least three years after treatment. If a woody plant is to be completely killed, roots as well as tops, it is necessary for the brush control chemical to be translocated from the above ground portion of the plant where it is applied, to the roots. No evidence of consistent translocation with basal sprays of 2,4,5–T in oil on bear oak has been found in these field trial tests.

Optimum *topkill* three years after treatment was obtained by carefully and completely encircling the basal portion of the stems with treating solution. Best *topkill* results were obtained by treating in early winter (November to January) while the poorest results were obtained in late fall (late August to early October). Concentrations of 2,4,5–T esters in oil below 1.5 percent to 2 percent by volume (6 pounds to 8 pounds active acid equivalent per 100 gallons solution) did not produce consistent results. There was little variation, how-

ever, between concentrations above these levels. Use of high volumes produced *topkill* more quickly.

High order results, in terms of *topkill not resprouting,* require that the treating solution cover the root collar of the plant. Best results were obtained by early winter treatments. Low concentrations (below 1.5 percent to 2 percent by volume) produced erratic results. High volumes were necessary to obtain superior *topkill not resprouting* after three years.

BRIEF PAPERS

A Note on the Translocation and Metabolism of Monuron[1] in Velvetbeans

THOMAS J. MUZIK, HÉCTOR J. CRUZADO, and M. P. MORRIS[2]

SELECTIVE herbicides have been used for many years. Some newer herbicides, such as the substituted ureas, recently have come into prominence. These have shown great promise for weed control in agricultural and non-agricultural land. Although a great deal of practical knowledge has been accumulated, additional research is needed regarding their mode of action on plants. In a previous study (1) it was shown that monuron was translocated from the roots to the stems and leaves of velvetbeans. The present experiments were undertaken to determine the period of time for monuron entry and its rate of metabolism and disappearance in velvetbean *(Stizolobium deeringianum* Bort).

Velvetbean plants 3 weeks old, growing in sand-filled pots in the greenhouse and watered daily with a complete nutrient solution, were used in this experiment. Each treatment was replicated four times. There were 2 plants per pot and 100 plants per replication. Forty milliliters of an aqueous solution containing 100 ppm monuron was poured onto the sand of each pot. The plants were cut off 1 cm. above ground level 1, 4, 7, 11, 14, and 18 days later. Untreated plants were cut at the same height at the time of treatment and 18 days later. Fresh and dry weights of each replication were recorded.

The plants cut 1 day after treatment showed no apparent effects from the monuron. Only mild symptoms had developed after 4 days; but these increased daily until the plants were dead after 18 days. The average fresh weight of foliage per replication of 100 treated plants decreased from 334.2 grams to 50.8 grams over this period. The dry weight remained relatively constant (Table 1). Only the plants cut 4 days after treatment had a dry weight significantly greater than the controls cut at the time of treatment.

The samples were ground, and the monuron content determined both chemically and biologically. The chemical analyses, using the method of Bleidner, et al, (2) showed that the concentration of monuron in the foliage increased up to about the seventh day, after which it decreased. The difference between the concentration of monuron at 7 days and at 14 days was highly significant. The weight of monuron per 100 plants was 23 mg. after 4 days, and 16 mg. after 14 days (Table 1).

Biological analyses of these same samples were made. Water extracts were prepared by agitating 10 g. of material in 500 ml. of water and allowing the suspension to stand overnight. These extracts were filtered, and 50 ml. added to the soil in which untreated velvetbeans were growing. These plants treated with extracts were observed for one month. Typical monuron symptoms developed in the plants

[1]CMU, (3 p-chlorophenyl)–1,1–dimethyl urea).

[2]Plant Physiologist, Agronomist, and Chemist, resp., Federal Experiment Station, ARS, USDA, Mayaguez, Puerto Rico.

Table 1. Dry weight and monuron content of velvetbean foliage at various times after addition of monuron to the roots.

Time after treatment, days	Dry weight of 100 plants, grams	Monuron content ppm	Weight of monuron per 100 plants, milligrams
0	41.3	0	0.0
1	46.1	160	7.4
4	47.3	493	23.3
7	42.6	513	21.8
11	43.2	419	18.1
14	43.8	375	16.4
18	42.6	425	18.1
18 (control)	60.0	0	0.0
LSD 5 percent	5.5	87	(calculated)
1 percent	7.5	119	

treated with the extracts. Plants treated with extracts prepared from velvetbeans exposed to monuron for 1 day exhibited mild symptoms. Those treated with extracts of velvetbeans exposed to monuron for 11 days exhibited severe symptoms. The plants were then cut 1 cm. above the ground, and the fresh and dry weights determined. These biological tests were semi-quantitative in nature. They did not indicate conclusively that the concentration of monuron gradually decreased after reaching its maximum.

The chemical and biological tests thus are in substantial agreement in regard to the accumulation of monuron in the leaves of treated plants. Growth ceased about 4 days after the monuron was applied to the roots, which was about the time that the first symptoms appeared. The amount of monuron increased in the leaves up to about the 4th to 7th day, after which it decreased. These experiments also demonstrated that monuron can be extracted from the leaves of velvetbean plants after it has been applied to the roots. During the metabolic process the concentration of monuron in the leaves decreased slowly.

A recent report by Cooke (3) presents evidence that monuron in very low concentrations effectively inhibits the Hill reaction. Cooke states that "it appears likely that CMU (monuron) is inhibiting photosynthesis in the plant at the light end of the reaction."

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Inhibition of Plant Growth by Some Nitrophenylureas

BURTON R. ANDERSON, VERMAN C. BACHMAN, STANLEY R. MCLANE and EDWARD W. DEAN[1]

A NUMBER of urea derivatives were found by Thompson et al.[2] to inhibit plant growth. Interest in the phenylureas had increased following the development of monuron, 3–(*p*-chlorophenyl)–1,1–dimethyl urea, as a useful herbicide. Research on these compounds with respect to their use as weed killers was initially conducted by E. I. du Pont de Nemours and Company. Subsequently, work was conducted by the USDA and many Experiment Stations throughout the country. Several examples of nitrophenylureas are included in U.S. Patent No. 2,705,195 which was assigned to the du Pont Company in 1955.

For the present investigation twelve nitrophenylureas were synthesized for testing as plant growth inhibitors. Preliminary trials with beans, oats and tomatoes showed the dicotyledonous plants to be affected more severely than oats. Black Valentine bean was selected as a test plant for more precise tests and grown in the greenhouse at 80°F. Plants were treated on the eighth day after planting when the primary leaves were two-thirds full size and the terminal buds tight. Plants were sprayed at rates equivalent to 0.25, 0.5 and 1.0 pounds per acre. Compounds were dissolved in ethyl cellosolve containing 0.5% "Tween 20" surfactant. The experiment was replicated twice and was divided each time according to rate. Treatments within each rate were randomized and included untreated controls and monuron as a standard. Every treatment contained five pots with two plants per pot making a total of ten plants per treatment. Observations were made twelve days after spray application.

For quantitative comparisons, measurements were made of stem elongation and fresh weight of tissue above the node bearing primary leaves and of area of the first trifoliolate leaf. Results are expressed as percentage reductions of untreated controls (Table 1) and represent an average of two replications. Analysis of variance was made, and because of the small size of the experiment, the one percent level of significance was used throughout. Tukey's formula for sequential range value was used to determine significance of means. The stem-length criterion showed no significant difference among rates and as such was not useful in discriminating between compounds. Repressions of leaf area and of fresh weight did show significance among rates.

Monuron and 3–(3–nitro–4–chlorophenyl)–1,1–dimethylurea were clearly more effective as inhibitors than the other compounds but did not differ appreciably from each other. Introduction of a nitro

[1]Specialist Third Class, Specialist Third Class, Plant Physiologist, and Agronomist respectively of the Chemical Corps, Fort Detrick, Frederick, Maryland.

[2]Thompson, H. E., Swanson, C. P., and Norman, A. G. New growth-regulating compounds. I. Summary of growth-inhibitory activities of some organic compounds as determined by three tests. Bot. Gaz. 107:476–507. 1946.

Table 1. Effect of nitrophenylureas when applied at several rates per acre on black valentine bean.

Chemical	Leaf-area red—pct			Fresh weight red—pct			Stem length red—pct			Comments
	0.25	0.5	1.0	0.25	0.5	1.0	0.25	0.5	1.0	
3-(*p*-Chlorophenyl)-1, 1-dimethylurea (monuron)	89.5	98.9	99.4	93.9	99.1	99.7	89.2	97.1	98.8	Death of leaf tissue and entire plant at higher rates; leaves nearly yellow; new leaves pale green.
3-(3-Nitro-4-chlorophenyl)-1, 1-dimethylurea	92.2	93.5	96.6	94.5	94.4	97.8	92.5	93.8	97.1	Similar to monuron; at lower rates primary leaves mottled green-yellow.
3-(*o*-Nitrophenyl)-1-methylurea	42.5	45.9	52.7	52.9	55.3	58.7	51.4	62.1	59.6	Primary leaves pale yellow at margins.
3-(*o*-Nitrophenyl)-1, 1-dimethylurea	35.3	64.3	67.5	50.7	68.4	81.4	51.4	70.8	80.0	Dead tissue on primary leaf margins increasing with rate.
m-Nitrophenylurea	24.6	31.9	27.5	35.5	38.4	37.6	36.3	39.1	34.3	Repression not increasing with rate.
3-(*m*-Nitrophenyl)-1-methylurea	62.9	44.3	62.2	60.3	53.1	73.2	50.5	47.3	71.4	Primary leaves mottled, yellow.
3-(*m*-Nitrophenyl)-1, 1-dimethylurea	49.1	59.5	63.1	61.9	70.9	74.8	51.4	61.7	69.4	Primary leaves mottled, yellow; dead tissue at higher rates.
3-(*m*-Nitrophenyl)-1-methyl-1-ethylurea	29.3	40.5	59.1	36.5	52.8	72.2	29.7	31.3	70.2	Primary leaves slightly yellow.
3-(*m*-Nitrophenyl)-1, 1-diethylurea	17.9	12.4	21.6	21.6	20.6	25.9	11.3	30.0	22.1	
3-(*p*-Nitrophenyl)-1-methylurea	-4.2	9.1	25.8	3.9	-2.8	22.1	8.5	8.2	12.7	
3-(*p*-Nitrophenyl)-1, 1-dimethulurea	-2.4	17.3	40.7	1.6	10.6	26.5	-10.8	13.6	29.4	Convex curling of leaflets at higher rates.
3-(*p*-Nitrophenyl)-1-methyl-1-ethylurea	3.0	2.7	14.1	3.9	-5.6	26.5	0.0	5.4	27.4	
3-(*p*-Nitrophenyl)-1, 1-diethylurea	3.6	8.1	7.8	10.7	7.5	7.6	16.1	2.1	7.8	

group to the meta position of monuron apparently does little to alter the activity. Since this addition is an extra step in synthesis, this urea probably has little use as a herbicide, although extensive screening might reveal weed-crop situations in which it is superior to monuron.

Concerning the remaining ureas, it is clear that a nitro group in the ortho or meta position produces more effect than one in the para position. All compounds, except *m*-nitrophenylurea and 3–(*m*-nitrophenyl)–1,1–diethylurea differed from the *p*-nitro compounds.

An interesting variation in response is produced by changing the alkyl substituent in a given nitrophenylurea. In the incomplete series of compounds available, it appears that a nitrophenylurea with a dimethyl alkyl substitution is the most effective in a series. Lengthening the chain from one to two carbon atoms decreases inhibition and removing the alkyl groups does the same. In the meta series 3–(*m*-nitrophenyl)–1,1–dimethylurea was the most potent compound. Its inhibition was generally greater than 3–(*m*-nitrophenyl)–1–methylurea but not significantly so. The unsubstituted and diethyl compounds were least effective in the series. The two *o*-nitrophenylureas did not differ from each other nor from their corresponding *m*-nitro analogs, suggesting that the meta and ortho series are equally effective as inhibitors. The para series was of low activity, and no differences in response were observed, except for 3–(*p*-nitrophenyl)–1,1–dimethylurea which produced formative effects in leaves. At the 0.25 pound rate it was inactive; but at the 0.5 pound rate it was more active than the other *p*-nitro compounds in the leaf-area repression test and at the one pound rate its effectiveness was greater even than that of m-nitrophenylurea and 3–(*m*-nitrophenyl)–1,1–diethylurea. On the basis of its formative effect this compound can be termed the most active in the para-substituted series.

A Method for Evaluating the Control of Waterweeds with Herbicides[1]

JESSE M. HODGSON[2]

IN recent years there has been an increasing interest in chemical control of plant growth interfering with water delivery in irrigation systems. Extensive chemical testing has been and is now in progress (1, 2). Under field conditions it is usually possible to make only one experimental treatment in each ditch. This makes comparing results from different treatments difficult because of the extreme variation of conditions from one irrigation ditch to another. Also, only a few chemicals can be tested and large amounts are needed to treat individual ditches.

Recent work in Montana shows that the use of an isolation box to establish several plots in a single ditch overcomes these disadvantages. It provides a means of evaluating several treatments under similar conditions. It does not, however, eliminate the necessity of whole ditch treatments in the final evaluation of new herbicides for waterweed control.

During the 1955 irrigation season various chemicals were tested for the control of submersed pondweeds *(Potamogeton* spp.) growing in an irrigation ditch. A metal box open at the top and bottom was placed in the ditch to isolate plots of waterweeds for exposure to the chemicals for the desired time.

This isolation box was found to be effective and practical for comparing the effects of different chemical treatments on submersed waterweeds in irrigation ditches.

The metal box was constructed of 14 gauge galvanized metal. Dimensions of the box were 2 feet wide x 4 feet long x 3 feet high. A piece of 1-inch angle iron was attached around the top to give rigidity and aid in handling of the box. Handles were also attached at each end.

In a typical trial the box was placed in a ditch heavily infested with submersed pondweeds. The ditch was about 6 feet wide and had a capacity of 8 cubic feet per second. The lower edge of the box was pushed 1 to 2 inches into the silt to prevent leakage of water and chemical during the treatment. Water flow in the ditch continued around the box during the treatment. Lath stakes were placed at each end of the box on the bank opposite the box to mark the plot. The waterweed growth immediately around the box for about 1 foot was trimmed away during the treatment.

In testing the suitability of the isolation box 5 herbicides were applied each at 2 concentrations. Each treatment was duplicated

[1]Report of cooperative investigations of the Field Crops Research Branch, ARS, USDA; the Huntley Branch of the Montana Agric. Exp. Sta.; and Region 6 of the Bureau of Reclamation, USDI. Montana Agric. Exp. Sta. Paper No. 395 Jour. Series.

[2]Agronomist, Field Crops Research Branch, ARS, USDA, Agronomy and Soils Dept., Montana State College, Bozeman, Montana.

giving 20 plots in a small area of 1 ditch. The volume of water inside the 2 x 4-box was easily determined from the total depth (d) in inches since each inch of depth contained 5 gallons. The amount of a chemical, liquid in ml. or solid in grams, needed to give a desired concentration (ppmv or ppmw) of the active ingredient (AI) could be subsequently calculated from the following formula:

$$\text{Amount of chemical (milliliters or grams)} = \frac{(5 \times d) \times 3785 \times \text{ppm}}{1{,}000{,}000 \times (\%\text{AI in chemical} \div 100)}$$

The chemical for each treatment was mixed thoroughly with 1 quart of water before applying. It was then applied with a 3-gallon compressed air sprayer at 50 psi. The nozzle of the sprayer was held beneath the water surface in the box during treatment and moved back and forth for thorough mixing of chemical and water. Each treatment was maintained in contact with the waterweeds for 30 minutes.

The metal box was then tipped up allowing clear water to flush the treated water off the plot and flow down the channel. The chemically treated water briefly passed over other plots as it moved down stream, however, contamination was considered negligible since the treated water was diluted and moved out in a few seconds.

Estimates of plant topkill in each plot were made weekly for the next 4 weeks. These estimates were averaged for each plot and are presented in Table 1.

Table 1. Response of pondweeds to several chemical treatments using the isolation box.

Chemical	Concentrate in water ppm	Percent topkill of pondweeds		
		Rep. I	Rep. II	Average
Dehydroabiethylamine acetate[3]	100	40	55	47
Dehydroabiethylamine acetate	200	53	52	52
Aromatic solvent	440	73	58	65
Aromatic solvent	640	77	85	81
Commercial herbicidal oil	640	0	11	5
Commercial herbicidal oil	1280	28	23	25
Orthodichlorobenzene	220	73	80	76
Orthodichlorobenzene	440	93	87	90
2,3-Dichloronaphthoquinone	20	17	10	12
2,3-Dichloronaphthoquinone	100	13	13	13

[3]Formerly referred to as Rosin amine D acetate or RADA.

Two of the chemicals in the test, dehydroabietylamine (RADA) and aromatic solvent, have been tested previously in this area. The previous tests were on the basis of treating an entire ditch rather than a small plot within a ditch. The results with these two chemicals indicated that they were rated more toxic in the whole ditch tests in 1954 than in the isolation box test in 1955.

The results in 1955 showed orthodichlorobenzene to give the greatest kill. In this test the aromatic solvent was considerably less

toxic than orthodichlorobenzene. RADA ranked third in order of toxicity in 1955 and was somewhat less effective than in 1954. The commercial herbicidal oil, even at the very high rate of 17.6 gallons per cfs, did not give effective control of pondweeds. This oil contained 55 percent aromatics. 2,3–Dichloronaphthoquinone was not effective on pondweeds at the concentrations and exposure time tested.

This technique of establishing plots for chemical waterweed treatments under field conditions will aid in preliminary evaluation of herbicides for control of submersed aquatic weeds. Treatments that prove the most promising in tests of this kind will still need to be evaluated by entire ditch tests before recommendations are made.

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Simplifying Weed Counts[1]

K. F. Best[2]

Weed counts have always been a tedious undertaking and efforts to improve the technique are continually being made. On the Experimental Farm at Swift Current we have added a few modifications to the standard counting frame which, in our opinion, saves considerably in time and labour. Our weed counts are generally taken in the seedling or early growth stages, and to aid in this work, the frames have been equipped with a handle as well as with two spike points. The points hold the frame firmly in place, while the handle eliminates the stooping down to retrieve the frame after each drop.

The frame, as well as the forked handle, is made of 3/16 inch steel rod. The frame is brazed between the tines of the handle so that the sharpened points extend about an inch and a half below the frame. Experience has shown that this type of sampling is faster and less fatiguing.

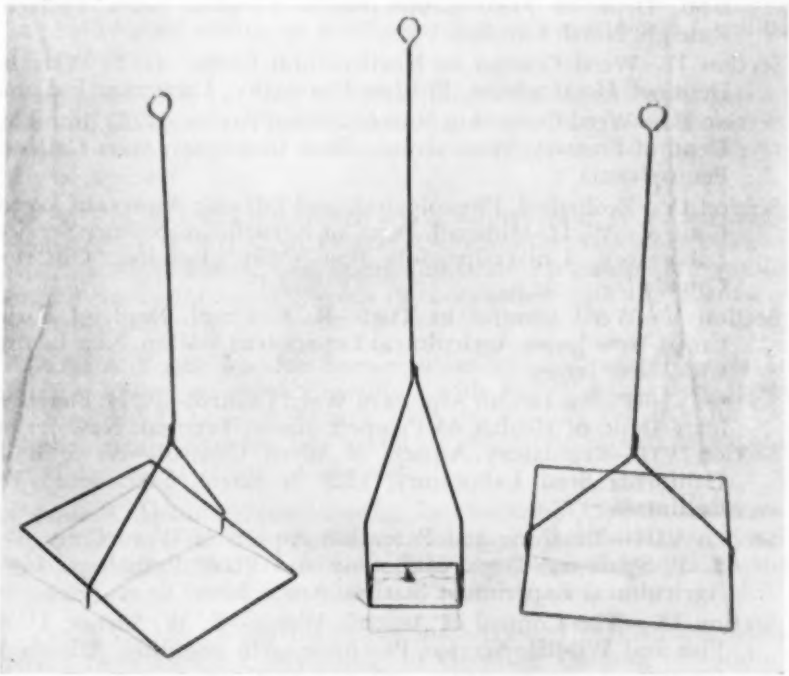

Figure 1. Sampling frames used for weed counts.

Figure 1 shows the three types of frame which are most commonly used for weed work at Swift Current. The sizes, from left to right, are 10 x 14 inches, 5½ x 5½ inches, and 12 x 12 inches.

[1]Contribution from the Experimental Farms Service, Canada Department of Agriculture, Ottawa.

[2]Research Officer, Field Husbandry Section, Experimental Farm, Swift Current, Saskatchewan.

News and Notes

W. B. Ennis, Jr., president of the WSA, has announced that plans are well underway for the 1958 meeting of the WSA to be held in conjunction with the Southern Weed Conference, January 13, 14 and 15 at the Peabody Hotel in Memphis, Tennessee. Titles of all papers intended for presentation at the meeting should be forwarded to the sectional program chairmen by August 1, 1957. Three copies of an abstract, that should not exceed 300 words, should accompany the title. It is essential that abstracts be submitted by the specified time so that they can be made available by the time of the meeting.

The program committee for the 1958 meeting of the WSA consists of A. S. Crafts, W. K. Porter, Jr., G. D. Hill, G. F. Warren, and W. C. Shaw, chairman. Sectional program chairmen are as follows:

Section I—Weed Control in Agronomic Crops—W. G. Westmoreland, Dept. of Field Crops, North Carolina State College, Raleigh, North Carolina

Section II—Weed Control in Horticultural Crops—G. F. Warren, Dept. of Horticulture, Purdue University, Lafayette, Indiana

Section III—Weed Control in Non-cultivated Areas—W. C. Bramble, Dept. of Forestry, Pennsylvania State University, State College, Pennsylvania

Section IV—Ecological, Physiological, and Edaphic Aspects of Weed Control—W. H. Minshall, Dept. of Agriculture, Science Service Laboratory, University Sub Post Office, London, Ontario, Canada

Section V—Weed Control in Turf—R. E. Engel, Dept. of Farm Crops, New Jersey Agricultural Experiment Station, New Brunswick, New Jersey

Section VI—Public Health Aspects of Weed Control—A. H. Fletcher, State Dept. of Health, 65 Prospect Street, Trenton, New Jersey

Section VII—Regulatory Aspects of Weed Control—W. S. Ball, California Seed Laboratory, 1220 N Street, Sacramento 14, California

Section VIII—Teaching and Extension Aspects of Weed Control—E. P. Sylwester, Dept. of Botany and Plant Pathology, Iowa Agricultural Experiment Station, Ames, Iowa

Section IX—The Control of Aquatic Weeds—E. W. Surber, U. S. Fish and Wildlife Service, Peachtree—7th Building, Atlanta 5, Georgia

O. E. Rud has accepted a position as assistant professor with the Virginia Agricultural Experiment Station, Blacksburg, where he will be concerned with the control of weeds in field crops, pastures and woodlands. Mr. Rud was formerly employed by the Agronomy Department, North Carolina State College, Raleigh.

F. W. Slife, Dept. of Agronomy, Univ. of Illinois, Urbana, was elected president, Lyle Derscheid, Dept. of Agronomy, South Dakota

State College, vice president, and Dwight Lambert, Nebraska Dept. of Agriculture and Inspection, Secretary and Treasurer, by the NCWCC for 1957. The 1956 meeting of the NCWCC, held in the Sherman Hotel, Chicago, on Dec. 10, 11 and 12, was attended by approximately 650 weed workers.

The Research Committee of the Western Weed Control Conference meet at the Owyhee Hotel in Boise, Idaho, on March 19 and 20, 1957. The general meeting of the Conference is to be held in Spokane, Washington, early in 1958.

In January 1957 the headquarters of Robert N. Andersen, Weed Investigations Section, U.S.D.A., were changed from Fargo, North Dakota, to St. Paul, Minnesota, where he will continue to conduct weed control research in sugarbeets.

Kenneth L. Hill accepted a position with the Weed Investigations Section, U.S.D.A., in September, 1956, to assist Donald E. Moreland in physiological studies on weed control in cotton at North Carolina State College.

In June 1956, G. Neil MacRae joined the Weed Investigations Section, U.S.D.A., at Phoenix, Arizona, to conduct investigations in weed control research in field crops in cooperation with the University of Arizona.

Franklin D. Aldrich accepted a position with the Weed Investigations Section, U.S.D.A., at Denver, Colorado, in November 1956, to conduct physiological, ecological and herbicide evaluation studies on the control of aquatic weeds in cooperation with the Bureau of Reclamation.

Peter A. Frank, who has been conducting weed control studies in Parma, Idaho, accepted a position with the Weed Investigations Section, U.S.D.A., in February 1957, to conduct research on the physiological, ecological and herbicide evaluation aspects of aquatic weed control at Denver, Colorado.

James L. Hilton, Weed Investigations Section, U.S.D.A., was transferred from North Carolina State College to Beltsville, Maryland, in November, 1956. He will conduct physiological studies on the mechanisms of herbicidal action.

Orvid W. Lee, Weed Investigations Section, U.S.D.A., was transferred from Laramie, Wyoming, to Corvallis, Oregon, to conduct weed control research in seed production of forage crops.

Robert E. Wilkinson joined the Weed Investigations Section, U.S.D.A., in January, 1957 to conduct studies on the control of aquatic weeds at Clarkedale, Arkansas.

In June of 1956, Thomas N. Johnson, Jr., was employed by the Weed Investigations Section to conduct studies on juniper control at Flagstaff, Arizona.

Donald N. Hyder was transferred from the Dept. of Interior to the Weed Investigations Section, U.S.D.A., on July 1, 1956. He will conduct research on the control of weeds and brush on rangelands at the Squaw Butte-Harney Experiment Station, Burns, Oregon.

Harry M. Elwell, Weed Investigations Section, U.S.D.A., was recently transferred from Guthrie, Oklahoma, to Oklahoma A & M, Stillwater, Oklahoma, to continue brush and weed control research in pastures and rangelands.

Lars Jensen has been appointed extension specialist in weed control at North Dakota Agricultural College, Fargo, North Dakota. He replaces Russ Widdifield who has been transferred to other duties.

John Hanson started work on physiological aspects of weed control on November 1, 1956. He is a plant physiologist in the Dept. of Agronomy, University of Illinois, Urbana.

The largest group of weed workers ever to attend a Northeastern Weed Control Conference met at the Sheraton-McAlpin Hotel in New York City January 10, 11 and 12, 1957. C. O. Cartwright, county agricultural agent of Essex County, Massachusetts received the award as the county agent having the most outstanding program on weed control in the Northeastern region. Awards for outstanding research were given to A. J. Kerkin and R. A. Peters of the University of Connecticut for their studies in seedling legumes and to W. C. Bramble, W. R. Byrnes, and D. P. Worley of Pennsylvania State University for their work in brush control. C. L. Hovey was elected president for the coming year. Other officers include S. N. Fertig as vice president, R. J. Aldrich as secretary and D. A. Schallock as treasurer.

The 1957 meeting of the Southern Weed Conference, held in Augusta, Georgia on January 23, 24 and 25, was attended by about 225 persons. E. G. Rodgers, Univ. of Florida, Gainesville, was elected president, Richard Behrens, U.S.D.A., College Station, Texas, was elected vice-president and Walter K. Porter, Jr., Louisana State University, Baton Rouge continued as secretary-treasurer. The next meeting of the conference will be held in Memphis, Tennessee, January 13, 14 and 15, 1958, when the Southern Weed Conference will be host to a meeting of the Weed Society of America.

Sustaining Members

American Chemical Paint Company, Ambler, Pennsylvania
American Cyanamid Company, New York, New York
American Smelting and Refining Co., Central Research Laboratories, South Plainfield, New Jersey
Asplundh Tree Expert Company, Jenkintown, Pennsylvania
Association of American Railroads, Chicago, Illinois
Chemical Insecticide Corp., Brooklyn, New York
Chipman Chemical Company, Inc., Bound Brook, New Jersey
Crag Agricultural Chemicals Division, Carbide and Carbon Chemicals Co., New York, New York
Deere and Company, Product Research Dept., Moline, Illinois
Diamond Alkali Company, Cleveland, Ohio
The Dow Chemical Company, Midland, Michigan
E. I. duPont deNemours & Company, Inc., Grasselli Chemicals Dept., Wilmington, Delaware
G.L.F. Soil Building Service, Ithaca, New York
Geigy Agricultural Chemicals, Div. of Geigy Chemical Corp., Yonkers, New York
Hercules Powder Company, Wilmington, Delaware
International Harvester Company, Chicago, Illinois
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National Aluminate Company, Chicago, Illinois
Olin Mathieson Chemical Corp., Baltimore, Maryland
O. M. Scott and Sons Company, Marysville, Ohio
Spraying Systems Company, Bellwood, Illinois
Stauffer Chemical Company, New York, New York
Swift and Company (Plant Food Division), Chicago, Illinois
United States Borax and Chemical Corp., Los Angeles, California

BIBLIOGRAPHY OF WEED INVESTIGATIONS
for
July, August, and September, 1956

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UNITED STATES DEPARTMENT OF AGRICULTURE
Agricultural Research Service
Field Crops Research Branch

This bibliography of current literature on weeds and their control is issued as a service to those engaged in weed research in the United States and other countries. In issuing this bibliography the Field Crops Research Branch, Agricultural Research Service, U.S.D.A. does not assume responsibility for the subject matter cited.

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